Mathematical Models and societal impact of CoVID-19 Pandemic: a short review

Abstract:

In this article we present a short and informative review on growth and impact of novel corona virus appeared in 2019. Almost entire world has been is the victim of this life-threatening virus. Here, we have discussed the growth of the covid 19 in different parts of the world and how they are mathematically modelled. We have also discussed how different mathematical models predicts the minimisation of the growth by predicting the minimum days of lockdown. Further, the effect of effect of lockdown in everyday life and its societal impact are also highlighted.

Keywords: Mathematical Models of CoVID-19, Social and Economic effect of CoVID-19

1. Introduction:

The potentially severe COVID-19 is an acute respiratory infection caused by the novel corona virus 2(SARS-CoV-2) with symptoms ranging from mild common cold to a severe viral pneumonia leading to acute respiratory distress that is potentially fatal. COVID-19 has beendeclared as a pandemic on 11th March, 2020 by World Health Organization (WHO). Though the existence of the corona virus is not new, with time it has spread fromanimal (bat) to human body and the existence of such virus was previously reported in China before the pandemic appeared. The rate of spread of CoVID19 banishes every country to initiate the lock down. The major aim was to minimise the spread of the virus as well as the casualty. Forthe countries like Italy, USA, Spain, India etc., the number of new cases were increasing day by day even after the declaration of lockdown by the respective government. The numbers of infected people were following a different trend of increasing for different country. Any natural phenomena are generally found to follow the exponential growth or decay, but in case of corona virus, the number of new cases per day was not at all exponential for all the countries. Many people had predicted the lockdown extension date by modelling the growth as exponential nature. Hence, it was a challenging job to model the growth and to forecast the number of total affected people. There has been a long history of research on epidemic deceases in statistical physics. Simple mathematical models and fitting the variation with different polynomial can be useful for understanding and predicting the epidemic spreading. However, the accurate prediction of any epidemic spreading is very difficult due to the uncertainty of any modelling. So far some of the models show that the 49 days lockdown without any break could reach the baseline. Also, sometimes the data may not be so reliable like the bird flu and SARS when the number of affected people and deaths were

misrepresented to hide the extent of the epidemic. This type of problem may increase theuncertainty of the prediction and interpretation. Still, the scientific interpretation of the spreading of any epidemic deceases helps the government to understand its spreading and to take the necessary steps. The main problem of forecasting is that the general people fear about the forecasting and prediction of the spreading like Spanish flu which killed about 50 million people worldwide (1918-1920) and lasted almost 18 months. Despite this uncertainty, people have given model, prediction, and forecast on COVID 19 epidemic.

In this article we have reviewed different models predicted for growth of CoVID-19 and the effect of CoVID-19 in society. In the first part, different models are discussed with their prediction and shortcomings. Here, two models are mainly highlighted; the simplest one is exponential growth model and the second one popular SEIR model. Both the models are used to explain the statistical data collected from available at that time. In the second part the effect of CoVID-19 in socio-economic status is described and how the mental health was also affected during that time, is also highlighted.

2. **Mathematical Model:**

(a) Polynomial Model:

In order to investigate the growth of the current epidemic COVID 19, different countries were taken into consideration. The main highlight of this model is to forecast the minimum number of lockdown days required to control the growth of the virus. China, being the source ofthe epidemic, made their lock down first on 23rd of January, 2020. Followingthis Italy, Spain, USA, and India imposed lockdown on later time. Th no. of affected people in first 21 days was considered to predict the minimum no lockdown days required. The new cases detected per day duringlockdown are used to generate the polynomial nature of the curve (daily

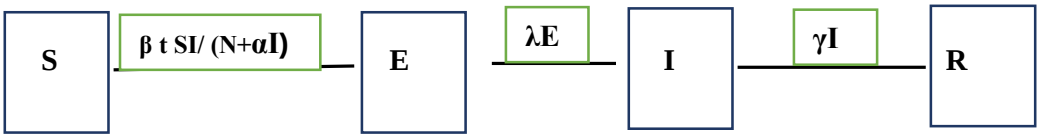
cases plotted with the number of days passed sincelockdown). Thedifferentcountries show different data but thevariation of new cases per day with the no. of days seemed to be almostidentical fashion for all the countries except China. To provide a mathematical nature, the data for all the countries were fitted andlinearly and 4-degree polynomial. However, it was quite difficult to fit the data exponentially with those data points. Thebest fitted graphs are considered with those fitting covering themaximum data points.The coefficients of the higher order polynomial are used to calculate the no. of days required to impose lockdown. The coefficients of the polynomial are function of time. Such nature of the coefficients was also used to establish a relation between growth and medication of the CoVID -19 affected people. The entire model is summarised in the equation:

$N(t) = N_0 + N_1(t) - N_2(t) - N_3(t)$ where $N_i(t) = 1 + c_1(t)\, x + c_2(t)\, x^2 + \ldots$. upto order 4.

Here t denotes the time and x denotes the number of lockdown days required(Bhowmik et al., n.d.).(Mukherjee et al., n.d.)

(b) SEIR Model:

The entire population can be split into four different categories: Susceptible (S), Exposed (E), Infectious (I), and Recovered (R). A schematic diagram of the SEIR model in shown in the Fig below.



A set of ordinary differential equations can be formed:

$dS/dt = -\beta\, t\, SI/(N+\alpha I)$……(1)

$dEdt = \beta\, t\, SI/(N+\alpha I) - \lambda E$…….(2)

$$\frac{dI}{dt} = \lambda E - (\gamma + \mu) I \quad \ldots\ldots\ldots\ldots (3)$$

$$\frac{dR}{dt} = \gamma I \quad \ldots\ldots\ldots\ldots\ldots (4)$$

where N= the total population of a country, $\beta(t)$ is the time dependent transmission rate, λ the daily rate of exposed individuals becoming infectious, μ the rate of death due to virus, γ the recovery rate from virus, and α can be thought of as parameter to measure the awareness of the population against the pandemic. As noted above, all parameter except $\beta(t)$ are assumed to be constant. The reason for time dependence of $\beta(t)$ is mainly due to quarantine and lockdown measures that is aimed to beconsider. More precisely, onecan assumes an exponential lockdown function between as described in the exponential model or polynomial modelin$[t_0, t_1]$ time intervals. With different boundary conditions, these set of equations can be solved to find out a relation between the number of infected and recovered people, which can help to minimise the process of lockdown(Kadyrov et al., n.d.)(de Noordhout et al., 2017; Knobler et al., 2004)

3. Socio-Economic Effect:

The coronavirus infection disease (COVID–19) had influenced the social life and the economic activities throughout the entire world.The mathematical model of spreading and its preventions are already discussed in the previous section. It had affected the daily life of the peoplein both socially and economically. Several developed countries like USA, Italy, Germany, France etc. got severe challenges to combat the situation even though they have protective infra structure. However, in case of India like developed countries this CoVID–19 had a large impact on society and due to not having sufficient infrastructures, the number of days of lockdown increased which was a nightmare for the people living below the

poverty line. The several impacts on society in terms of health, economy,poverty, transportation, tourism etc. are discussed in the upcoming section below(Ahmed & Sifat, 2021).

(a) Impact on healthcare facility

The most challenges faced during the epidemic was Impacts of any infectious disease on health sectors are moststraightforward as it directly influences the society. The health care facilitiesof developed countries like Italy, Germany, UK, USA etc., had faced a challenge during the epidemic. Since, India is a developing country as well as large population country, providing healthcare support to many infected people is a nightmare. Especiallyin rural cities due tolack of health care infrastructure such as number of hospitals, enough isolated beds,ventilators and even the distance from urban cities, the rural people suffered a lot. Only 30% of our populations in urban areas are beingserved by the 75% of the doctors, whereas 70% of our populations inrural areas are being served by 25% of the doctors [(Bhowmik, 2020)]. The ratio of healthcare professional to the population is less in both rural and urban areas. According to the data of NationalHealth Profile-2019, there were only 0.53 hospital beds per 1000people of India [(Ahmed & Sifat, 2021)]. At the start of epidemic, there was a huge shortage of N95 masksand PPE for the health care workers. The other patients in emergency like those suffering from cancer, kidney dialysis, pregnant women dueto the shortage of medicines, unavailability of the health service etc faced a serious trouble.During this time, several alternative ways were found to fulfil the necessity of the healthcare infrastructure. Unused buildings, trains and playgrounds were turned into covid isolation room. Doctor consultancy were also carried out in virtual mode, to avoid

less probability of contamination. However, the government tookneedful steps after those incidents.

(b) Impacts on essential commodities and itstransportation

Essential commodities and their transportation related to each other. Though the government permitted to sell the essential commodities such asfoods, groceries, medicines during the full lockdown through grocery and e-commerce. However,the government had assured common people not to panic forthe essential things. Some shops were selling essentials items at muchhigher rates than compared to normal price. At that situation the online groceriesrestored operations in larger cities, but due to lack of workers, deliverywas still unavailable in rural areas. Several E-groceries systems like BigBasket and Grofers, several e-commerce like Flipkart and Amazon were also suffered a lot to deliver product in expected time. Since, the economy fluctuates, 35% of sellers predict that thesales would be decreased due to consumer's financial situation, supplychain disruptions and product shortages. In this coronavirus pandemicsituation, from the fear of infection, so many people are avoiding instoreshopping and this may increase a sudden demand of e-commerceas many consumers turn to online shopping to avoid in-store shopping.

(c) Economic Impact:

The most significant impact was the effect on economy during COVID–19. It affected the country with strong economic background like USA [(Saji et al., 2020)]. Indianeconomy had been badly affected during this pandemic.Supply chains have been disrupted for the lockdown restriction. Various private industries such as airlines,restaurants, hotels, multiplex etc., are closed and they

are deductingsalaries or even terminating their employees [(Bhowmik, 2020)]. The economicanalysts have estimated that the lockdown may have cost the Indianeconomy 7-8 lacs crores during 21 days only. It will affect the GDP lossin the economy. Major companies have suspended somefactories across the country. Entertainment Management Associationestimated losses at around Rs.3000 crore because of the cancellations ofconferences and big shows [(Ahmed & Sifat, 2021)]. Majorities of employees from privateinstitutions are going to lose their job. From the third week of March,e-commerce services like Flipkart and Amazon have stopped theirnon-essential products in India; even the e-groceries like BigBasketand Grofers have restricted their services. There is a large impact onfilm industry also. Film releasing dates have been postponed to futuredates across the world; the global box office is dropped by billions ofdollars [(Bhowmik, 2020)]. As the government is mainly helping poor people, middleclass self-employed persons are suffering a lot in this lockdown. Thegovernment has already announced a huge package in this situation,which will affect the overall economy.

(d) Impact on poor people

The people living below the poverty linesuffered a critical situation during pandemicin India. Since, those people did not have fixed monthly incomecost of the people in India are not having fixed monthlyincome, they have been in a big trouble. Many migrant workers whowork in different states are spending critical time outside their homewithout any income. Many workers are suffering from starvation.However, government has initiated the rationing system to thosepeople also, but still all the workers are not getting sufficient ration. Asper the United Labour body warning,

about 400 million people workingin informal system are at risk of falling deeper into poverty due to thecoronavirus crisis [18d]. This will affect many people and leave them asjobless.

(e) Psychological impact

The pandemic due to novel coronavirus created fear, stress,anxiety, and loneliness among thepeople after the lockdown was announced. The serious effect was on senior citizens due to lack of negligence caused by social distancing. The family visits were been stopped by the authority to protect contamination in old age homes, resulting loneliness, fear, and anxiety in old-age homes.In this pandemic situation, with increasing number of contaminated people, senior citizens and above were in stressed about their near ones. It was evident from the scenario in 2003 during SARS epidemic that affected people having age above 65. [27d]. A study by William Gardner *et al.*, elaboratesthe risk factors of elderly people and their associate people taking care of them. [(Gardner et al., 2020)]. Hence, it was a liability for the society to take care the older age people in priority.

(f) Some positive impacts on society

Besides all these negative sides and hurdles lockdown in India has provided a golden opportunity for people to spend their time with family. Moreover, during this lockdown several other ways like online teaching, work from home and many like others were explored, which will continue in post covid world. The most beneficiary side of the lockdown was not only to stop the spread of the novel corona virus, but during the lockdown, the nature became free from environmental pollution. The animals got a space in this world during this lockdown situation as most of the people are staying at home.

(g) Suggestion for further research:

The hammer and dance models can be studied rigorously to understanding the upcoming short and long waves of novel corona virus. Further with this above discussion, it is now open challenge to think about the precautionary measurement regarding the aspects discussed above.

Conclusion:

In this article, we review the mathematical models proposed at time of pandemic to combat the daily number of affected people as well as lockdown. All these mathematical models, discussed above, were able to highlight the growth for a particular country. However, those models are not perfect and possesses an incompleteness. The daily life of the people living in urban as well as rural areas are discussed with socio-economic status of our country. This article will help not only to visualize the entire scenario of the country as a precaution for further appearance of such pandemic, rather it will also help mathematician to develop more accurate theoretical model to predict the possible ways to combat such pandemic.

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