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A simple mathematical model to predict and validate the spread of Covid-19 in India

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ABSTRACT

The new outbreak of the corona virus (Covid-19) is expanding rapidly worldwide, disrupting millions and prompting authorities to take swift measures to avoid the disease. National lockdown imposed by the Indian government since 25 March 2020, the early lockdown action shows as compared to many other Countries/states can benefit from limiting the final size of the epidemic. A report on the issue of spreading the Covid-19 modeling in India is under review. This study analyzes Covid-19 infections by 20Dec 2021 and presents a mathematical approach for forecasting new cases or cumulative cases in practical situations. This forecast is much needed to schedule/continue medical set-ups for possible action to tackle the Covid-19 outbreak. It is important to mention here that the number of authors has proposed different models for predicting the expansion of Covid-19 to India and other countries; almost no model has yet to be demonstrated viable. With this mathematical model, it is simple to forecast the transfer of Covid-19. It is clear from the data that lockdown has played a significant role in controlling the transmission of the disease. A close match between the predicted empirical results and the available results proves the derived model similarity.

Selection and peer-review under responsibility of the scientific committee of the 3rd International Conference on Computational and Experimental Methods in Mechanical Engineering.

1. Introduction

As reports showed, a pandemic of unknown pneumonia started in Wuhan, China, in December 2019, but there are reports that it began by the end of November 2019 [1,2]. A new variant of the corona virus COVID-19 similar to SARS-CoV, for which health experts have approved no valid medicine or vaccine. This virus is transmitted by the respiratory tract or by contact with infected particles or pathogenic organisms over an incubation period of 2 to 14 days [3,4]. Until then, the world could be protected by various preventive measures; COVID-19 pandemic has taken over the entire globe. Over an early duration of 4 months, many as five million cases are publicly revealed, with much more than 300,000 causalities in over 150 countries [5,6]. COVID-19 is not explicitly treated, and the mortality rate varies across different countries and ranges from 2 to 15 percent [7,8]. The epidemiological data verify that the spread rate is very high, and the WHO confirmed that SARS-CoV is

* Corresponding author. E-mail address: harishkumar@nitdelhi.ac.in (H. Kumar). about 10 times fatal [9]. Fig. 1 illustrates the countries reporting Covid-19 cases in the globe. It can see that Covid-19 cases are registered in each country except in two nations around the world [10]. Fig. 2 shows a map of India and various states of India, with an estimated number of Covid-19 infections reported to date [11].

1.1. Present scenario

It is essential to determine the needed potential facilities, which may be necessary for terms of hospitals, beds, ventilators, medicines, etc. In regards to health personnel including doctors, nurses, and support personnel, a variety of researchers, including physicists, biologists work for thorough evaluation and further consequences of their developed model in the study of infected data, recovered data, and death rates. Infection, recovery, and mortality rates depend not only on the form of Covid-19 but also on the country's reaction. In this scenario, the researcher would like to examine data on infected, recovered, and dead people in India directly compared with other countries and the worldwide mean. The specific modeling was designed and evaluated by a few

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Fig. 1. Countries reported Covid-19 infections so far [10].



Fig. 2. States of India showing Covid-19 infections so far [11].

researchers, and their findings were presented [12–15]. Some of the models are discussed below, along with their brief concept and shortcomings.

Julia R Gog (2020) explained the classic epidemic susceptible-i nfectious-recovered (SIR) model, a very simple model proposed in the 1920 s. It is called the SIR model, and S is the number of people who are susceptible to disease but have not been infected so far, I form the number of people who are ill, and R are the people who are either dead or healed from infection [16,17]. SanglierContrearas (2020) suggested the prediction of COVID-19's epidemiological progress through modeling, analysis, and interpretation of data, and recommending various quadratic equations and appears to fit for critical data evaluation. The multiple factors studied and evaluated are the number of people infected, the death rate, the number of people recovered, the duration of treatment, etc. [18]. Rashad Eletrey (2020) investigates the impact of evolutionary adaptations, referring COVID-19 on the transmission of processes in complex networks [19].

GianlucaMalato (2020) evaluated the pattern of infected persons using a mathematical model based on a logistic model (equation 1) and an exponential model (equation 2) for publicly available data through the portal of the Government of Italy. The data was compared to the actual data available for far, and a critical consistency is obtained with significant deviation. X is the time in the equation, a, b, c are parameters/variables [20].

Tain-Mu-Chen, et. Al. (2020) provided a mathematical model is used to simulate the transmissibility process of the novel coronavirus in China. He used Berkeley Madonna 8.3.18 software (developed by R Macey and G Oster at Berkeley University of California) to match the data collected from the competent Chinese authority, which is in the public domain [21].

In a recent work researchers have analyzed the global impact of Covid-19 with emphasis given on daily cumulative infections and cumulative deaths. The data for Europe and Americawere analyzed and impact was judged in relation to the data for the worldfor Covid-19 outbreak [22].

However, due to limitations, only specific mathematical models are listed here, but at the same time, researchers and practitioners are seeking to create/examine current statistical/mathematical methods in times of hardship for the human race. On further observations, authors have found that the models proposed by various researchers are focused on the constraints depending on a specific city o country and are not accurate for each area. Different constants assumed/evaluated in different models, as discussed above, are very specific, limiting the use of models as general-purpose models. Addressing the limitations, authors present simple mathematical models based on extensive data available in India (the first case of Covid-19 reported in India on 30 January 2020, the confirmed cases then reached to 100,000 on 19 May 2020 andcrossed11046000 cases up to now), which do not include different particular constants / computed factors [11]. The relevant data and subsequent evaluation of the mathematical model are described in the following section.

2. Methodology

Fig. 3 gives a brief glimpse of Covid-19 spread in India. One can find the confirmed cases of Covid-19 in India as on 20 Dec 2020.



Fig. 3. Impact of Covid-19 in India since reporting of first case until Dec20, 2020.

The data for each state has been shown in tabulated form in table 1. The same information of cumulative sum of different parameters since inception for India are shown in Fig. 3. Out of the total infected people so far, the cured, deaths and infected are represented in form of pie-chart through Fig. 4.

Authors have attempted a number of different generalised mathematical models to predict some function for cumulative infections, cumulative recoveries, cumulative deaths and cumulative active infections, few of them areQuartic / bi-quadratic regression, exponential function, sum of sine function, Gaussian model,

Table 1

Statistics of the Covid-19 information as on Dec20, 2020 [11].

1Andma nand Nicobar Islands881614722882Andma Pradesh878,737076867,44542023Andma Pradesh16,5005016,500254Assam16,6001017210,8093525Bihar247,2441320240,9154776Chandigarh247,2401320240,9154777Chatitigarh267,21030818,3284378Dadra and Nagar Haveli and Daman and Diu1640116219Delni610010,27756,55011,8610Caq257,64923148,37197211Ga257,649232,98644,22119,80512Haryana113,251010112,56858813Himachal Pradesh232,986446,221196614Jamura Mi Kashmir118,263111,05112,56816,00015Jarkhand113,021010113,07170816Karataka909,66121080,0035717Kerla132,54381,114,85313,1818Jarkhand13,2543372,54616,5019Laksha/weep000020Madinya Pradesh13,25434114,85513,1821Malaya Pradesh13,2543372,56416,5123Meghalya13,25	S. No.	State / Union Territory	Total cases	Deaths	Recoveries	Active cases
2Andma Pradesh787.237076867.44542023Anunachal Pradesh165.005516.35025.34Asam215.4091017210.86935.315Bihar247.244135.2240.91549776Chandigarh19.0733181247.48016.557Othattisgarh267.2193181247.48016.558Dadra and Nagar Haveli and Dama and Diu16401163.219Delhi617.00510.27786.58010.14810Gaarat235.299423.4219.22511.84011Gujarat235.299423.4219.22511.84012Haryana257.6442821248.93558813Himachal Padesh5.32986446.22110.8014Jammu and Kashmir118.263184111.258385415Jarkhad118.263184111.25861.60016Karnataka909.46912.00982.94414.9717Kerala10010.30710.80110.30710.80118Lakshdweep0000020Madhy Pradesh21.25838.1637.1635.1619Mabarashtra13.027.64837.736.64616.5121Makanashtra13.26313.4112.62049.9113.1822Maghaly13.27313.44 </td <td>1</td> <td>Andaman and Nicobar Islands</td> <td>4881</td> <td>61</td> <td>4732</td> <td>88</td>	1	Andaman and Nicobar Islands	4881	61	4732	88
3Arunachal Pradesh16,6305516,302254Asam215,0401017210,86035235Bihar247,244152240,91549776Chandigarh267,2193181247,48016,5587Chattisgarh267,2193181247,48016,5588Dadra and Nagar Haveli and Daman and Diu16401103219Delhi617,00510,277596,58010,48410Goa50,06472148,33797211Gujarat235,29984446,221118,4012Jagman257,6442821248,93558813Himachal Pradesh118,2631841112,568385414Jammu and Kashmir118,2631841112,568385415Jarkhand909,46910010,407170816Karnatak909,46112,09982,94444,97117Kerala705,870 <u>2817</u> 61,40811,41818Ladshdweep000020Madhya Pradesh1,826,51848,7641,783,90562,74323MglaJaya13,21413,81414,6491,53134524Major13,22413,81414,6491,53261,60523MglaJaya13,22413,81414,6491,5313518Ladshdweep0000	2	Andhra Pradesh	878,723	7076	867,445	4202
4Asam215,001017210,86935235Bibar217,244135220,91549776Chandigarh19,07330818,3284377Chhattisgarh267,2193181247,48016,5818Dafar and Nagar Haveli and Daman and Diu640116219Delhi617,00510,277596,58010,14810Goa506,6472148,37197211Gujarat235,2994234219,22511,84012Hangana235,299423446,221519613Himachal Pradesh52,2986446,221519614Jammu and Kashmir118,2631841112,568385415Jarkthand102,50101011,03,07178816Karnataka909,46912,00982,94414,49717Kerata705,8702817641,2851,31818Ladakh92712480035519Lakshadweep0000020Madnya Pradesh13,253134112,64511,31821Maharabtra13,90513,24333725,646166523Maghalya13,25313412,6204992424Maharabtra13,0413,25313415,22361825Majalad163,04226139,57114,2224,343 <td>3</td> <td>Arunachal Pradesh</td> <td>16,630</td> <td>55</td> <td>16,350</td> <td>225</td>	3	Arunachal Pradesh	16,630	55	16,350	225
5Bihar247,2441352240,91594776Chandigarh19,07330818,3284377Chhattisgarh267,2193181247,48016,5588Dadra and Nagar Haveli and Daman and Diu16401163219Delhi10,07510,27759,58010,14810Goa50,06472148,37197211Gujarat257,6442821248,935588812Haryana257,6442821248,935588613Himachal Pradesh52,32986446,221519614Jamu and Kashmir113,0251010110,307170816Karnataka90,46912,00982,94414,49717Kerala705,8702817641,28561,60018Ladakh92791248003519Ladakhaveep00010,30719Ladakh31,284348121,64616621Maharashtra13,25313417,830562,74322Maihya Pradesh13,25313412,62049924Mizoran13,25313421,64616623Maharashtra13,25313412,62049924Mizoran13,25313433,05712,42225Nagaland163,04250112,22351824Mizoran13,253144 <td>4</td> <td>Assam</td> <td>215,409</td> <td>1017</td> <td>210,869</td> <td>3523</td>	4	Assam	215,409	1017	210,869	3523
6Chandigarh19.07330818.3284377Chattisgarh267.2193181247.48016.588Dadra and Nagar Haveli and Daman and Diu16401163219Delhi617.00510.277596.58010.14810Ca60.06472148.37197211Gujarat235.2994234219.22511.84012Haryana55.23986446.221519614Jammu and Kashmir118.2631811112.568385415Jarkthard118.2631010110.0307170816Karnataka909.46920.009882.94414.49717Kerala705.8702112880.0035518Ladakh9279124880.0035519Lakshadweep000020Mahya Pradesh13.284348117.83.90562.74321Maharashtra13.95.1848.7461.783.90562.74322Mainpur13.2313412.62049924Maharashtra13.25313412.62049925Magalad89012986.57.7734525Magalad163.042501152.23.0061.7226Odisha800.99.90101152.23.9561.8327Puluchery98.99.66174498.1534.1428Mizaram65.9	5	Bihar	247,244	1352	240,915	4977
7Chhatisgarh267,2193181247,48016,5588Dadra and Nagar Haveli and Dama and Diu16401163219Delhi617,00510,277596,58010,14810Goa50,06472148,37197211Gujarat532,5994234219,22511,84012Haryana532,5994234248,93558813Hinachal Pradesh52,32986446,221519614Jamnu and Kashnir118,2631841112,568385415Jharkhand118,2631841113,258385416Karnataka90,46912,00982,94414,49717Kerala705,8702817641,28561,60018Ladakh9279124880,0435519Lakshdweep000020Madhya Pradesh231,2843481216,48511,31821Maharshtra132,5313412,62049922Manipur132,5313412,62049923Meghalaya132,2313412,62049124Mizoram132,2313412,62049525Nagaland163,04277436515226Oisha89012983,531561827Puducherry37,4862636,77734528Punjab65,9361733	6	Chandigarh	19,073	308	18,328	437
8Dadra and Nagar Haveli and Daman and Diu16401163219Delhi617,00510,277596,58010,14810Goa235,2904234219,22511,84011Gujarat235,29086446,22158813Himachal Pradesh52,32986446,221519614Jammu and Kashmir118,2631841112,568385415Jarkhand113,0251010110,30770816Karnataka909,46912,00982,94414,49717Kerala705,8702817641,28561,60018Ladakh27912488003519Lakkhadweep0002,74321Maharashtra31,2843372,54616523Mapilaya Pradesh32,53413412,63015,27324Maipur31,23313412,63015225Magland1809026Odisha89012936315227Puducherry37,74885,315134,0315228Nagatana13,034152,22314214229Nagatana636,8111,983785,315152,22329Rajasthan636,8111,814151,303152,22330Sikkim57312,424498137429Nagatana668,9111,93773,	7	Chhattisgarh	267,219	3181	247,480	16,558
9Delhi617,00510,277596,80610,14810Goa50,06472148,37197211Gujarat235,2994234219,22558812Haryana257,64286446,22159613Himachal Pradesh52,32986446,22158814Jammu and Kashmir118,2631841112,56888415Jharkhand113,0251010110,307170816Karataka909,46912,00982,94414,49717Kerala705,870217641,28561,60018Ladakh9279124880035519Lakshdweep000020Madhya Pradesh231,2843481216,48511,31821Maharashtra13,25313425,64666523Maghalya13,2531342,62049924Mizoram13,25313412,62049925Nagaland890129876510727Puducherry37,74882055618395712,42228Punjab63,04250113,83512,42230Sikkim57312448,11437437431Tamil Nadu806,89111,98378,51395332Plangana28,996261728,59712,42231Tamil Nadu806,89111,983<	8	Dadra and Nagar Haveli and Daman and Diu	1640	1	1632	1
10Goa50.6472148.37197211Gujarat235.294242.40219.22511.84.0112Haryana257,644281.00248,93558813Himachal Pradesh52.32986446.22.1519614Jammu and Kashmir118.263101.01110.307170815Jharkhand113.025101.0110.307170816Karnataka909.46912.009882.94444.49717Kerala705.870281.7641.28561.60018Ladakh927.912.4880035519Lakshadweep0000020Mahya Pradesh231.284348.1216.48511.31821Maharashtra1.896.51848.7461.783.90562.74323Mejhalya31.2843372.504616524Mizoram13.25313412.62049924Mizoram13.25313412.5251825Nagaland13.27313412.52561826Olisha8012987510727Puducherry37.4862636.77734528Punjab63.0425201152.23561829Sikkim63.0425201152.31559331Tami Nadu806.89111.9375.31559332Felagana28.144151.3 <td>9</td> <td>Delhi</td> <td>617,005</td> <td>10,277</td> <td>596,580</td> <td>10,148</td>	9	Delhi	617,005	10,277	596,580	10,148
11Gujarat235,994234219,22511,84012Haryana235,6442821248,935588813Himchal Pradesh5,23986446,21519614Jammu and Kashmir118,0631841112,568385415Jharkhand113,0251010110,307170816Karnataka909,46912,009822,94444,49717Kerala705,8702817641,28561,60018Ladakh909,409124880035519Lakshadweep000020Madhya Pradesh231,2843481216,48511,31821Maharashtra1396,51848,7461,783,90562,74322Mainjur27,648131325,646166523Meghalaya13,25313412,62049924Mizoram13,25313412,62049925Nagaland18209026Odisha8012936,77734527Puducherry37,74862636,77714,42228Punjab65042573124498137429Rajasthan806,8911,983755,153959331Tamil Nadu806,8911,983755,013569433Tipura33,164151327,013688833Tipura33,16411,983 <td< td=""><td>10</td><td>Goa</td><td>50,064</td><td>721</td><td>48,371</td><td>972</td></td<>	10	Goa	50,064	721	48,371	972
12Haryana257,6442821248,935588813Himachal Pradesh52,32986446,21519614Jammu and Kashmir118,2631841112,568385415Jharkhand113,0251010110,307170816Karnataka909,46912,00982,94414,49717Kerala705,8702117880035518Ladakh9279124880035519Lakshadweep000020Madhya Pradesh31643481216,48511,31821Maharashtra1.896,51848,7461,783,9052,74322Manipur27,64833725,64616523Meghalaya13,25313412,62049924Mizoram4122736315225Nagaland1809026Odisha8012986,77734527Puducherry37,74862633,7434528Punjab163,042501152,233561829Rajasthan89,996214489,1337431Tamil Nadu806,8911,98335,31559332Telangana31,6437522,50957534Uttar Athand296128243349033Tipura31,64536,828365,009,69777,711 <t< td=""><td>11</td><td>Gujarat</td><td>235,299</td><td>4234</td><td>219,225</td><td>11,840</td></t<>	11	Gujarat	235,299	4234	219,225	11,840
13Himachal Pradesh52.329.86446.221.519614Jamku and Kashmir118,2631841112,568385415Jharkhand113,0251010110,03770816Karnataka909,46912,00982,94414,49717Kerala7082817641,28561,60018Ladakh927,9712480035519Lakshadweep000020Madhya Pradesh21,2843481216,48511,31821Maharashtra13,25313412,62046522Manipur27,64833725,64616523Meghalaya13,25313412,62049924Mizoram12,22336315215225Nagaland1809026Odisha80129876516727Puducherry37,74862633,7434528Punjab163,0425201152,223561829Rajasthan89,99621728,95712,42231Tamil Nadu806,89111,983785,31559332Telangana31,64151327,013688833Tipfura31,64151323,0995734Uttar Athand296128260,09777,7135Uttar Athand296128200,09777,71<	12	Haryana	257,644	2821	248,935	5888
14Jammu and Kashmir118,2631841112,568385415Jharkhand110,0251000110,30770816Karnataka909,46912,009882,94414,49717Kerala705,870 <u>2817</u> 641,28561,60018Ladakh927912488003519Lakshadweep000020Madhya Pradesh231,2843481216,48511,31821Maharashtra1,396,51848,7461,783,90562,74323Meghalaya13,25313412,62049924Mizoram13,25313412,62049925Nagaland1809026Oidisha890129876510727Puducherry37,748626136,77734528Punjab573124498137430Sikkim573124498137431Tamil Nadu86,89111,98375,315959333Tripura33,16437532,01368833Tufpana31,6437424,4349036Uttar Ahand296,1228,28960,00717,77136West Bengal266236,736389,736389,73736West Bengal536,82960,0050,69717,77136West Bengal568,28960,0050,69717,	13	Himachal Pradesh	52,329	864	46,221	5196
15Jharkhand113,0251010110,077770816Karnataka909,46912,00982,94414,49717Kerala905,8702817641,28561,60018Ladakh9279124880035519Lakshadweep000020Madhya Pradesh231,2843481216,4851,31821Maharashtra1,896,51848,7461,78,90562,74322Maripur27,64833725,646166523Meghalaya13,25313412,62049924Mizoram1809025Magaland1809026Odisha890129875,7734527Puducherry37,748520115,22334528Punjab163,0425201152,23312,42230Sikkim5573124498137431Tamil Nadu806,89111,98385,315959332Pilagana28,144151327,01368833Tripura31,64428624349034Uttarkhand29612824349036Wittarpadesh286,82836050,69717,71136Wittarpadesh56,82836050,69717,714	14	Jammu and Kashmir	118,263	1841	112,568	3854
16Karnataka909,46912,009882,94414,49717Kerala705,8702817641,28561,60018Lakahaf9279124880035519Lakshadweep000020Madhya Pradesh231,2843481216,4851,31821Maharashtra1,896,51848,7461,783,90562,74322Manjpur26,64833725,64666,5123Meghalaya13,25313412,62049924Mizoram41227396315225Nagaland890129876,550726Odisha890129876,5510727Puduberry37,748626,4336,77734528Punjab163,04250115,223561829Rajasthan288,996261723,895712,42230Sikkim5573124498137431Tamil Nadu806,89111,98378,315959332Felangana31,6437532,5092734Uttrakhand29612824349035Uttrakhand29636,82836050,69717,7136West Bengal56,82836050,69717,71	15	Jharkhand	113,025	1010	110,307	1708
17Kerala705,870 <u>2817</u> 641,28561,60018Ladash9279124880035519Lakshadweep000020Madhya Pradesh31,2843481216,48511,31821Maharashtra1,896,51848,7461,783,90562,74322Mainpur27,64833725,646166523Meghalaya13,25313412,62049924Mizoram1227396315225Nagaland1809026Otisha890129876510727Puducherry37,74862667,77734528Punjab63,042201152,223561829Rajashan5573124498137431Tamil Nadu806,8911,98373,01368832Telangana31,16437532,50925734Uttar Ahand296128243349035Uttar Pradesh2170202688236West Bengal217036,62836,62836,00509,6971,77136West Bengal56,8289360509,6971,771	16	Karnataka	909,469	12,009	882,944	14,497
18 Ladakh 9279 124 8800 355 19 Lakshadweep 0 0 0 0 20 Madhay Pradesh 21,284 3481 216,485 1,733,905 62,743 21 Maharashtra 13,896,518 48,746 1,783,905 62,743 22 Manipur 27,648 337 25,646 1665 23 Meghalaya 13,253 134 12,620 499 24 Mizoram 18 0 9 0 25 Nagaland 18 0 9 0 26 Odisha 8901 29 8765 107 27 Puducherry 37,748 626 36,777 3618 29 Rajasthan 503 291 152,223 5618 30 Sikkim 5573 124 4981 374 31 Tamil Nadu 806,891 1,983 78,315 9593 32 Telangana 21,414 1513 25,099 25,7 34 <td>17</td> <td>Kerala</td> <td>705,870</td> <td>2817</td> <td>641,285</td> <td>61,600</td>	17	Kerala	705,870	2817	641,285	61,600
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31 Tamil Nadu 806,891 11,983 785,315 9593 32 Telangana 281,414 1513 273,013 6888 33 Tripura 33,164 375 32,509 257 34 Uttarakhand 2961 28 2443 490 35 Uttar Pradesh 2170 20 2068 82 36 West Bengal 536,828 9360 509,697 17,711 Fotal 9,069,597 134,350 8,657,363 276,393	30	Sikkim	5573	124	4981	374
32 Telangana 281,414 1513 273,013 6888 33 Tripura 33,164 375 32,509 257 34 Uttarakhand 2961 28 2443 490 35 Uttar Pradesh 2170 20 2068 82 36 West Bengal 536,828 9360 509,697 17,771 Potestripter to the stander to the standert to the stander to the stander to the stander to the standerto t	31	Tamil Nadu	806,891	11,983	785,315	9593
33 Tripura 33,164 375 32,509 257 34 Uttarakhand 2961 28 2443 490 35 Uttar Pradesh 2170 20 2068 82 36 West Bengal 536,828 9360 509,697 17,771 Total 9,069,597 134,350 8,657,363 276,393	32	Telangana	281,414	1513	273,013	6888
34 Uttarakhand 2961 28 2443 490 35 Uttar Pradesh 2170 20 2068 82 36 West Bengal 536,828 9360 509,697 17,771 Total 9,069,597 134,350 8,657,363 276,393	33	Tripura	33,164	375	32,509	257
35 Uttar Pradesh 2170 20 2068 82 36 West Bengal 536,828 9360 509,697 17,71 Total 9,069,597 134,350 8,657,363 276,393	34	Uttarakhand	2961	28	2443	490
36 West Bengal 536,828 9360 509,697 17,71 Total 9,069,597 134,350 8,657,363 276,393	35	Uttar Pradesh	2170	20	2068	82
Total 9,069,597 134,350 8,657,363 276,393	36	West Bengal	536,828	9360	509,697	17,771
	Total		9,069,597	134,350	8,657,363	276,393



Fig. 4. Distribution of Covid-19 infections in India as on Dec 20, 2020.

Fourier series and sum of exponential function series with confidence level of 95%. But, there was not a single polynomialorder or function, which could be helpful in present scenario. Authors are hereby proposing the use of generalized polynomialregression of order 6 and discussing the function equations for cumulative infections, cumulative recoveries, cumulative deaths and cumulative active infections respectively as a function of time.Data for different functions as mentioned earlier are considered for first 115 days of spread of Covid-19 in India, i.e., during April 01 – Jul24, 2020. Table 2 summarizes the equation for each function with the R-squared value for better understanding. The model equations (as a function of time in terms of days) are used to plot the existing data from April 01 – Jul24, 2020and projection has

Table 2

Equation	for	different	functions.
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S. No.	Function for	Model Equation	R - Squared
1.	Cumulative infections (CI)	1E-06 * x ⁶ - 0.0007 * x ⁵ + 0.1751 * x ⁴ - 17.607 * x ³ + 791.72 * x ² -10431 * x	0.9998
2.	Cumulative recoveries(CR)	$\begin{array}{l} 8E\text{-}07 & * x^6 - 0.0006 & * x^5 + 0.1726 & * x^4 - \\ 18.97 & * x^3 + 912.71 & * x^2 - 14113 & * x \end{array}$	0.9999
3.	Cumulative deaths (CD)	9E-09 * x^6 - 6E-06 * x^5 + 0.0015 * x^4 - 0.1376 * x^3 + 7.4558 * x^2 -97.284 * x	0.9998
4.	Cumulative active infections (AI)	$\begin{array}{l} 1E\text{-}07 * x^6 - 5E\text{-}05 * x^5 + 0.0011 * \\ x^4 + 1.4914 * x^3 - 128 * x^2 + 3772.5 * x \end{array}$	0.9795

been madeto 20 days forward on the basis of these model equations. The plot of the same has been shown in Fig. 5 while Fig. 6 is supplied to compare the results of model equations with the actual plotted data for Covid-19 infections for first 115 days.

If we carefully analyse and compare the Fig. 5 with Fig. 3, we will see that on Day 130, (Aug13, 2020), the line showing number of cumulative active infected people is changing slope in having a small peak, thereafter the number will keep of reducing which indicates that the recovering people are more than the freshly infected people. It has been found that the projected and the actual data are in the good agreement exhibiting the similar pattern.

3. Results and discussions

This paper has attempted to investigate the spread of Covid-19 in India on the basis of information available through authenticated sources. India reported its first Covid-19 infection on January 30, 2020 and for about five weeks, there were very little or negligible infections reported across the country. During this period, lot of careful considerations were made by Government of India like thermal screening at airports, awareness among the citizens regarding Covid-19 and its spread, sanitization of probable or confirmed zones of Covid-19 infection etc. The Covid-19 infections started surging (per day reporting of fresh infections in two digits) in March 2020 and the Government of India imposed nation-wide lock-down with minimal / emergent connectivity to the rest of



Fig. 5. Projection of Function on the basis of model equations Vs span of time (days)upto Aug 13, 2020 (day 135).



Fig. 6. Actual data of Covid-19 infectionVs span of time (days)upto Jul 24, 2020 (day 115).

world and within country, there was no transport permitted with complete stop to industry, institutions, retails etc. excluding health, law and order sector.

Initially, as evident from the international databases, there Covid-19 infections grew in small number, but because of its propagating nature, soon the infections keep on rising and the country extended the lock-down on April 15, May 04 and May 18, 2020 respectively. As of now, about 972,121,246 Covid-19 infections reported so far (Day 264) with a propagation rate of approximately 5% per day. The databases have been used to investigate the pattern of spread of Covid-19 infections and the following parameters are investigated:

- (a) Cumulative infections, CI (derived from infections reported each day)
- (b) Cumulative recoveries, CR (derived from recoveries reported each day).
- (c) Cumulative deaths, CD (derived from deaths reported each day)
- (d) Cumulative active infections, AI (derived from active CI, CR and CD respectively)

Authors attempted to investigate different models reported and applied across the globe for prediction of spread of Covid-19 and felt that the models like SIR, SIRD and SIER, though have been applied through the globe, but they are dependent over various factors depending upon the circumstances over that location and may not be applied unilaterally to any situation. As of now, there has been enormous information available regarding Covid-19 infection, its spread; it is now possible to employ simple mathematical models to predict the same. Even in India, such models had been used by various researchers, but either their projections were very much conservative or too extrapolated, and hence did not able to present a practically viable model.

Authors have implied generalized regression model for critical investigation of Covid-19 infection information available regarding India and has used the information of 115 days to predict the future spread of Covid-19.Fig. 5 can be employed to make estimates/projections for Covid-19 infections on days in advance.

4. Conclusions

The following conclusions have been drawn from the investigation presented herewith:

(a) A detailed assessment of Covid-19 infection and related aspects regarding India has been presented.

- (b) Brief discussion regarding the recent work reported by various researchers through the globe is presented along with the mathematical models developed / implied by them.
- (c) A simple mathematical model for assessment of Covid-19 infections in India has been presented using generalized polynomial regression. The model equations for Cumulative infections (CI), Cumulative recoveries (CR), Cumulative deaths (CD), and Cumulative active infections (AI) are derived and the projected values are compared with information available regarding the same.
- (d) The Covid-19 infections are seen surging in the country from day 130 and a local peak of infections is expected with projections of decay in infection rate thereafter. The same can be validated through actual data plotted in Fig. 4 near to the day 130.
- (e) The predicted data for CD is found in close agreement with the actual CD value and its pattern. Predicted CD pattern has a little rise in slopebeyond the day 130,showing increase in cumulative deaths in the country per day. The similar pattern can be seen in the actual data for CD plotted in Fig. 4.

CRediT authorship contribution statement

Harish Kumar: Investigation. Pawan K. Arora: Methodology. Meena Pant: Writing - original draft. Anil Kumar: Writing review & editing. Shahroz Akhtar Khan: Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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