INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Uncertainty in the Spread of COVID-19: An Analysis in the Context of India

Mohit Soni[1]*, **Rajesh Kumar Sharma**[1], **Shivram Sharma**[2]

1 Department of Mathematics, Government Holkar Science College, Indore, M. P, India
2 Government P. G. College, Guna, M. P, India

OPEN ACCESS

Received: 02.06.2021
Accepted: 10.10.2021
Published: 10.12.2021

Citation: Soni M, Sharma RK, Sharma S (2021) Uncertainty in the Spread of COVID-19: An Analysis in the Context of India. Indian Journal of Science and Technology 14(42): 3157-3176. https://doi.org/10.17485/IJST/v14i42.1004

* **Corresponding author**.

sonimohit895@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objectives: Prevention measures play an important role in controlling infectious diseases. We eagerly want to know how to observe the impact of prevention measures, just by looking at the pandemic curve. To explain this impact, we observe that the graphical representation of an infectious disease on a logarithmic scale is more suitable compared to a linear scale. To achieve our result, we also verified that the curve of the cumulative confirmed cases of pandemic COVID-19 follows an almost exponential growth. Furthermore, we tested the flattening of the logarithmic curve, which indicates the effect of prevention measures are working well. **Methods:** We use the numerical and statistical method introduced by Baruh. We divided the cumulative confirmed COVID-19 data of 240 days into 12 equal parts (20 days per part) after the starting of the vaccination programme in India. We apply the exponential growth model to check the exponential growth of cumulative confirmed cases of COVID-19 on a linear scale and verify it by the comparison of the actual and the predicted values obtained by exponential model. Also, we compute the first difference of logarithmic cumulative confirmed cases and find its strong linear relationship with time 't'. Furthermore, we apply the student t-test to confirm the linear relationship between them. We find the number of days require to flatten the logarithmic curve. **Findings:** Our results show that the uncertainty of the cumulative confirmed cases of COVID-19 spread pattern may continue in the upcoming days. The logarithmic curve would be flattened within 127 days from 23rd August 2021. The logarithmic scale explains the impact of the prevention measures better than the linear scale. Because the flattening of the logarithmic curve appears earlier than the flattening of the linear scale. **Novelty:** In the context of India, our study exhibits the importance of graphic presentation of COVID-19 data and compare between the logarithmic scales to the linear scale. As per our knowledge, this kind of study is new in the context of India.

Keywords: COVID-19; Exponential growth model; Linear regression; Student t-test; Cumulative confirmed cases; Logarithmic scale

1 Introduction

Many methods and techniques are developed for forecasting a disease [1–11], although there is always some uncertainty involved with these forecasts. In India, the first confirmed case and the first death due to the corona virus were reported on 30th January 2020 and 11th March 2020 respectively [12,13]. According to the worldometer [14], the second-highest populated country India has a population density of 464 per Km^2 (1,202 people per mi^2). Since a viral disease has more chance to spread in a dense place, so in India, the chance of getting spread COVID-19 is more than in another country. COVID-19 is a viral disease that is caused due to SARSCOV2 virus. It spreads through the contact of air droplets of COVID-19 patients. When a susceptible person comes into contact with an infected person's air droplets, then they become infected. The dynamics of viral diseases are investigated by mathematical modeling of infectious diseases, where the population is divided into different compartments. Kermack et al. [15–17] considered the various compartmental models. Further, researchers, epidemiologists, and scientists discussed many epidemic models and introduced new parameters or compartments in the compartmental model.

In the primary stage, predictions through the auto-regressive integrated moving average (ARIMA) method worked well just for the short term. Predictions done by Poonia and Ajad [1,2] through the ARIMA (Autoregressive integrated moving average) method were approximately equal to the obtained experimental values. Pain, Bhaskar, and Rawoot [18] developed the SEIR (Susceptible, Exposed, Infectious, Recovered) model to analyze the disease. Pandey et al. [3] developed the SEIR epidemic model and the regression analysis. Ranjan [19] used epidemiological models for his predictions. Acharya et al. [20] examined resemblances between COVID-19 cases and the susceptibility at the state level. Rai et al. [4] observed data of twenty-one days from 14th March 2020 to 3rd April 2020 and used the model of exponential growth for their predictions. Li et al. [21] studied the connection between smartphone and COVID-19. Darapaneni et al. [22] used t-test and ANOVA test to check the impact on control of SARS-CoV-2 (Severe acute respiratory syndrome coronavirus-2). Bedi et al. [5] used a modified SEIRD (susceptible, exposed, infected, recovered, deceased) model and LSTM (Long short- term memory) model to make the prediction of COVID-19 cases in India and make the comparison between them. Pandey et al. [6] studied the data of COVID-19 to check the connection with health infrastructure and management of Indian states and districts. Jeffrey Chu [7] performed a statistical analysis of COVID-19 in Itali and Spain using SIR (Susceptible, Infected, Recovered) model and the log -linear regression model. They researched that in the both countries the curve of confirmed cases follows the exponential growth. Jahan et al. [23] studied the entry and initial spread of COVID-19 in India. Sengupta et al. [24] researched a cluster study of COVID-19 in India.

Our model is neither stochastic, nor deterministic. It is neither complicated nor complex. It is a simple exponential growth model based on the factor time 't' only. It helps to check the flattening of the logarithmic curve. And, this logarithmic curve indicates the status of COVID-19 more explicitly rather than exponential curve. Actually, an infectious diseases doesn't follow the linear trend generally. The growth rate keeps rising; this line can become almost vertical and seems to last forever. This may create the impression that measures such as social distancing, Mask wearing do not work properly. The logarithmic scale is very suitable for measuring the rate of change, especially the growth rate. That's why, we emphasis on the logarithmic curve.

"On a logarithmic graph of COVID-19 infections, even though the overall numbers are still increasing, you can see the point at which the rate of growth starts to level off when that exponential growth has stopped. "-Mathematician Bobby Seagull.

2 Data and Methodology

According to Baruah, [8–11], the spread of COVID-19 in India is growing exponentially. We collect the required data of cumulative confirmed of COVID-19 in India from the Johns Hopkins University [25]. We select the data after starting the vaccination program in India. We analyze the consecutive 240 days from 15th January to 11th September 2021.

To check the exponential growth of epidemic curve, we define an exponential function k(t) by the equation:

$$k(t) = e^{a+bt}, \ \ where \ \ \ a, b > 0, \ \ t \geq 0. \tag{1}$$

From equation (1), we get,

$$C(t) = logk(t) = a + bt. \tag{2}$$

This is linear in 't'. To use this model, we have to choose the value of 't' as a base, The value of the constant 'a' is already known. When the estimated values of 'b' are about the same, the trend has become nearly exponential. To compute 'b' at a time 't', we use cumulative confirmed cases for some days. As Δlog C(t) becomes constant, then the structure of the total number of confirmed cases tends to be almost exponential.

If Δlog C (t) performs the reduction, the structure of the total confirmed cumulative cases becomes almost logarithmic. It may not reach exactly zero otherwise the total number of confirmed cases remains stable in an unexpected way, but the 'S'

shaped arch for the models does not permit it. Therefore, the transform from the almost exponential structure to the almost logarithmic structure has just taken place, before the Δlog C (t) becomes zero. We are enthusiastic to recognize the shift from exponential to logarithmic, by assessing the data from 15th January 2021 to 11th September 2021. We divided this period into 12 equal parts, and each part has 20 days.

3 Result and discussion

We inspired by Baruh's work [24]. He used his own statistical method based on exponential model to study the pandemic COVID-19 situation in India, USA and world. Though our study durations different, yet our results are almost same. Previously, Semra Sevi et al.[26] studied how different ways of visually presenting COVID-19 data affect Canadian citizens' views, attitudes, and support for public policy.

To examine the trend of Δlog C(t), we split the data into twelve similar parts, as shown in Table 1D.

Table 1. Distribution of parts

Part	Duration	Exponential regression correlation coefficient r
1	2021-01-15 to 2021-02-03	0.999
2	2021-02-04 to 2021-02-23	0.999
3	2021-02-24 to 2021-03-15	0.996
4	2021-03-16 to 2021-04-04	0.993
5	2021-04-05 to 2021-04-24	0.992
6	2021-04-25 to 2021-05-14	0.998
7	2021-05-15 to 2021-06-03	0.989
8	2021-06-04 to 2021-06-23	0.992
9	2021-06-24 to 2021-07-13	0.999
10	2021-07-14 to 2021-08-02	0.999
11	2021-08-03 to 2021-08-22	0.999
12	2021-08-23 to 2021-09-11	0.999

The total confirmed values for each part is following an exponential growth that be verify by applying the exponential growth model $N = Ae^{Bt} where\ A > 0,\ B > 0,\ t \geq 0$. by the strong exponential regression correlation coefficient in table 1. For each part, the calculation is arranged in a tabular form. See table 2 to table 13.

Next, we arrange all the predicted values of Δlog C(t) in tabular form (table 14 and table 15) for the better comparison.

As we can observe that the average value of Δlog C(t) is decreasing from the first part to the second part, but after that, it is increasing continuously till the part 6. From the part 6, it decreases continuously till the part 11 and then slightly increase in the part 12.

Now we tabulated the linear equation and correlation coefficient of each part in the following table 16.

The linear relationship between Δlog C(t) and 't' can easily be detected by the above table 16. The value of the correlation coefficient shows that the linearity becomes stronger as time increases. But in the part 6, this linear relationship becomes weak. If we put Δlog C(t) = 0 in the 12th part linear equation, we get t = 127 days approximately, which means the logarithmic curve flatten within 127 days from the date 23th August 2021.

As Δlog C(t) reduce continuously, the pattern of growth would stay exponential.

As mentioned in the table 16 , the slopes increase part by part. Even the first part has a negative slope, but after that, the slope becomes positive and more positive. This means that the exponential trend has continued over time due to the strong positive linear trend between Δlog C(t) and 't'. The negative slope of this linear relationship indicates that the exponential pattern is beginning to convert in the log pattern .

The exponential growth of each part can be easily recognize in the following figures 1 to 12. In the following figures, we compared the actual and predicted value of total confirmed cases through the exponential growth model, $y = Ae^{Bt}$, where y is the cumulative confirmed cases, t is the time in days and A,B are positive constable. Both the curve of actual and predicted values almost coincide that indicate the cumulative confirmed cases follow exponentially growth.

Now, we compare the actual and the predicted values of Δlog C(t) for each part in the figure 13.

Our actual and predicted values of Δlog C(t) follow a strong trend in the figure 13 (iv), 13 (v), 13 (vi), 13 (vii), 13 (viii).

Figure 13 (i) shows that a decreasing linear trend between these two values, if it tends to zero (it cannot be exactly zero), then we can say that the exponential curve started to turn into a logarithmic curve.

Table 2. For part 1

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	1/15/2021	10542841	10545980.34	16.17096849	0.001438788	0.001374862
2	1/16/2021	10557985	10558972.86	16.17240388	0.001435395	0.001359724
3	1/17/2021	10571773	10571981.39	16.17370896	0.00130508	0.001344586
4	1/18/2021	10581823	10585005.95	16.17465916	0.000950194	0.001329448
5	1/19/2021	10595639	10598046.55	16.17596394	0.001304784	0.00131431
6	1/20/2021	10610883	10611103.22	16.17740161	0.001437672	0.001299172
7	1/21/2021	10625428	10624175.98	16.17877144	0.001369825	0.001284034
8	1/22/2021	10639684	10637264.84	16.18011223	0.001340789	0.001268896
9	1/23/2021	10654533	10650369.82	16.18150688	0.001394652	0.001253758
10	1/24/2021	10667736	10663490.95	16.1827453	0.001238425	0.00123862
11	1/25/2021	10676838	10676628.25	16.18359817	0.000852864	0.001223482
12	1/26/2021	10689527	10689781.73	16.18478592	0.001187756	0.001208344
13	1/27/2021	10701193	10702951.42	16.18587668	0.001090754	0.001193206
14	1/28/2021	10720048	10716137.33	16.18763708	0.001760404	0.001178068
15	1/29/2021	10733130	10729339.48	16.18885667	0.001219587	0.00116293
16	1/30/2021	10746174	10742557.9	16.19007123	0.001214565	0.001147792
17	1/31/2021	10757610	10755792.61	16.19113486	0.001063628	0.001132654
18	2/1/2021	10766245	10769043.62	16.19193723	0.000802366	0.001117516
19	2/2/2021	10777284	10782310.95	16.19296204	0.00102481	0.001102378

Table 3. For part 2

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	2/4/2021	10802591	10800314.85	16.19530746	0.001149274	0.00100808
2	2/5/2021	10814304	10812054.34	16.19639115	0.00108369	0.00100816
3	2/6/2021	10826363	10823806.59	16.19750563	0.001114477	0.00100824
4	2/7/2021	10838194	10835571.62	16.19859783	0.001092199	0.00100832
5	2/8/2021	10847304	10847349.43	16.19943802	0.000840193	0.0010084
6	2/9/2021	10858371	10859140.05	16.20045776	0.001019734	0.00100848
7	2/10/2021	10871294	10870943.48	16.20164719	0.001189435	0.00100856
8	2/11/2021	10880603	10882759.74	16.20250312	0.000855926	0.00100864
9	2/12/2021	10892746	10894588.85	16.20361852	0.001115401	0.00100872
10	2/13/2021	10904940	10906430.81	16.20473736	0.001118835	0.0010088
11	2/14/2021	10916589	10918285.65	16.20580502	0.001067662	0.00100888
12	2/15/2021	10925710	10930153.37	16.20664019	0.000835169	0.00100896
13	2/16/2021	10937320	10942033.99	16.20770225	0.001062068	0.00100904
14	2/17/2021	10950201	10953927.53	16.20887927	0.001177019	0.00100912
15	2/18/2021	10963394	10965833.99	16.21008337	0.001204094	0.0010092
16	2/19/2021	10977387	10977753.39	16.21135889	0.001275525	0.00100928
17	2/20/2021	10991651	10989685.75	16.21265745	0.001298556	0.00100936
18	2/21/2021	11005850	11001631.08	16.21394841	0.001290966	0.00100944
19	2/22/2021	11016434	11013589.4	16.21490962	0.000961209	0.00100952
20	2/23/2021	11030176	11025560.71	16.21615626	0.001246633	0.0010096

Table 4. For part 3

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	2/24/2021	11046914	11035148.76	16.21767258	0.001516324	0.001237
2	2/25/2021	11063491	11053455.24	16.21917206	0.001499476	0.001284
3	2/26/2021	11079979	11071792.09	16.22066125	0.001489199	0.001331
4	2/27/2021	11096731	11090159.35	16.22217203	0.001510775	0.001378
5	2/28/2021	11112241	11108557.09	16.22356876	0.001396734	0.001425
6	3/1/2021	11124527	11126985.35	16.22467378	0.001105018	0.001472
7	3/2/2021	11139516	11145444.18	16.22602026	0.001346477	0.001519
8	3/3/2021	11156923	11163933.63	16.22758168	0.001561417	0.001566
9	3/4/2021	11173761	11182453.75	16.22908974	0.001508061	0.001613
10	3/5/2021	11192045	11201004.6	16.23072473	0.001634997	0.00166
11	3/6/2021	11210799	11219586.22	16.23239899	0.001674253	0.001707
12	3/7/2021	11229398	11238198.66	16.23405664	0.001657652	0.001754
13	3/8/2021	11244786	11256841.99	16.23542603	0.001369395	0.001801
14	3/9/2021	11262707	11275516.24	16.23701848	0.001592449	0.001848
15	3/10/2021	11285561	11294221.47	16.2390456	0.00202712	0.001895
16	3/11/2021	11308846	11312957.73	16.24110673	0.002061132	0.001942
17	3/12/2021	11333728	11331725.07	16.24330454	0.002197809	0.001989
18	3/13/2021	11359048	11350523.55	16.24553609	0.00223155	0.002036
19	3/14/2021	11385339	11369353.21	16.24784796	0.00231187	0.002083
20	3/15/2021	11409831	11388214.11	16.24999684	0.002148879	0.00213

Table 5. For part 4

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	3/16/2021	11438734	11372382.29	16.25252681	0.002529965	0.00258
2	3/17/2021	11474605	11428530.34	16.25565783	0.003131019	0.00282
3	3/18/2021	11514331	11484955.6	16.25911393	0.003456103	0.00306
4	3/19/2021	11555284	11541659.45	16.26266432	0.00355039	0.0033
5	3/20/2021	11599130	11598643.25	16.26645159	0.003787276	0.00354
6	3/21/2021	11646081	11655908.4	16.27049123	0.004039636	0.00378
7	3/22/2021	11686796	11713456.28	16.27398116	0.003489931	0.00402
8	3/23/2021	11734058	11771288.28	16.27801706	0.004035899	0.00426
9	3/24/2021	11787534	11829405.82	16.28256404	0.004546982	0.0045
10	3/25/2021	11846652	11887810.3	16.28756681	0.005002767	0.00474
11	3/26/2021	11908910	11946503.13	16.29280838	0.005241567	0.00498
12	3/27/2021	11971624	12005485.74	16.2980607	0.005252327	0.00522
13	3/28/2021	12039644	12064759.56	16.3037264	0.005665692	0.00546
14	3/29/2021	12095855	12124326.03	16.30838436	0.004657964	0.0057
15	3/30/2021	12149335	12184186.59	16.31279597	0.004411607	0.00594
16	3/31/2021	12221665	12244342.7	16.31873173	0.005935765	0.00618
17	4/1/2021	12303131	12304795.82	16.32537532	0.006643591	0.00642
18	4/2/2021	12392260	12365547.4	16.33259363	0.007218306	0.00666
19	4/3/2021	12485509	12426598.93	16.34009024	0.007496613	0.0069
20	4/4/2021	12589067	12487951.88	16.34835029	0.008260053	0.00714

Table 6. For part 5

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	4/5/2021	12686049	12428301.23	16.35602445	0.007674152	0.008023
2	4/6/2021	12801785	12619813.38	16.36510618	0.009081735	0.008746
3	4/7/2021	12928574	12814276.61	16.37496147	0.009855293	0.009469
4	4/8/2021	13060542	13011736.39	16.3851172	0.01015573	0.010192
5	4/9/2021	13205926	13212238.9	16.39618726	0.011070052	0.010915
6	4/10/2021	13358805	13415831.03	16.40769731	0.011510057	0.011638
7	4/11/2021	13527717	13622560.38	16.42026229	0.012564982	0.012361
8	4/12/2021	13689453	13832475.29	16.43214729	0.011884999	0.013084
9	4/13/2021	13873825	14045624.86	16.44552559	0.013378298	0.013807
10	4/14/2021	14074564	14262058.93	16.45989083	0.014365235	0.01453
11	4/15/2021	14291917	14481828.11	16.47521577	0.015324946	0.015253
12	4/16/2021	14526609	14704983.79	16.49150372	0.016287949	0.015976
13	4/17/2021	14788003	14931578.15	16.50933791	0.017834185	0.016699
14	4/18/2021	15061805	15161664.19	16.52768374	0.018345838	0.017422
15	4/19/2021	15320972	15395295.71	16.5447443	0.017060551	0.018145
16	4/20/2021	15616130	15632527.34	16.56382605	0.019081758	0.018868
17	4/21/2021	15930774	15873414.56	16.58377442	0.019948369	0.019591
18	4/22/2021	16263695	16118013.69	16.60445705	0.020682627	0.020314
19	4/23/2021	16610481	16366381.94	16.62555562	0.021098573	0.021037
20	4/24/2021	16960172	16618577.39	16.64638953	0.020833904	0.02176

Table 7. For part 6

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	4/25/2021	17313163	17449641.31	16.66698885	0.020599321	0.02153186
2	4/26/2021	17636186	17771861.25	16.6854746	0.018485747	0.02117372
3	4/27/2021	17997113	18100031.22	16.70573315	0.020258556	0.02081558
4	4/28/2021	18376421	18434261.07	16.72659018	0.020857033	0.02045744
5	4/29/2021	18762976	18774662.72	16.74740739	0.020817205	0.0200993
6	4/30/2021	19164969	19121350.12	16.76860592	0.021198529	0.01974116
7	5/1/2021	19557457	19474439.35	16.7888785	0.020272578	0.01938302
8	5/2/2021	19925517	19834048.62	16.80752304	0.018644538	0.01902488
9	5/3/2021	20282833	20200298.33	16.82529674	0.017773704	0.01866674
10	5/4/2021	20664979	20573311.1	16.84396232	0.018665581	0.0183086
11	5/5/2021	21077410	20953211.81	16.86372375	0.019761432	0.01795046
12	5/6/2021	21491598	21340127.66	16.88318398	0.01946023	0.01759232
13	5/7/2021	21892676	21734188.18	16.90167408	0.018490096	0.01723418
14	5/8/2021	22296081	22135525.31	16.91993286	0.018258784	0.01687604
15	5/9/2021	22662575	22544273.41	16.93623684	0.016303973	0.0165179
16	5/10/2021	22992517	22960569.33	16.95069078	0.014453939	0.01615976
17	5/11/2021	23340938	23384552.46	16.96573078	0.01504001	0.01580162
18	5/12/2021	23703665	23816364.73	16.98115166	0.015420873	0.01544348
19	5/13/2021	24046809	24256150.71	16.9955243	0.014372638	0.01508534
20	5/14/2021	24372907	24704057.66	17.00899415	0.01346985	0.0147272

Table 8. For part 7

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	5/15/2021	24684077	24980204.15	17.02168039	0.012686242	0.0119667
2	5/16/2021	24965463	25172790.71	17.03301541	0.011335017	0.0115434
3	5/17/2021	25228996	25366862.02	17.04351599	0.010500585	0.0111201
4	5/18/2021	25496330	25562429.54	17.05405655	0.010540559	0.0106968
5	5/19/2021	25772440	25759504.8	17.06482774	0.010771191	0.0102735
6	5/20/2021	26031991	25958099.42	17.07484825	0.010020508	0.0098502
7	5/21/2021	26289290	26158225.12	17.08468368	0.009835434	0.0094269
8	5/22/2021	26530132	26359893.71	17.0938032	0.009119518	0.0090036
9	5/23/2021	26752447	26563117.07	17.10214801	0.008344808	0.0085803
10	5/24/2021	26948874	26767907.2	17.10946358	0.007315575	0.008157
11	5/25/2021	27157795	26974276.17	17.11718619	0.007722604	0.0077337
12	5/26/2021	27369093	27182236.15	17.12493646	0.007750275	0.0073104
13	5/27/2021	27555457	27391799.42	17.13172267	0.006786213	0.0068871
14	5/28/2021	27729247	27602978.33	17.13800979	0.006287117	0.0064638
15	5/29/2021	27894800	27815785.34	17.14396238	0.005952591	0.0060405
16	5/30/2021	28047534	28030232.99	17.14942281	0.005460426	0.0056172
17	5/31/2021	28175044	28246333.95	17.15395872	0.004535911	0.0051939
18	6/1/2021	28307832	28464100.95	17.15866062	0.004701897	0.0047706
19	6/2/2021	28441986	28683546.83	17.16338854	0.004727921	0.0043473
20	6/3/2021	28574350	28904684.56	17.16803157	0.004643032	0.003924

Table 9. For part 8.

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	6/4/2021	28694879	28804373.81	17.17224078	0.004209215	0.00377262
2	6/5/2021	28809339	28874779.28	17.17622172	0.003980933	0.00364624
3	6/6/2021	28909975	28945356.85	17.17970881	0.003487088	0.00351986
4	6/7/2021	28996473	29016106.92	17.18269632	0.002987513	0.00339348
5	6/8/2021	29089069	29087029.93	17.18588459	0.003188268	0.0032671
6	6/9/2021	29182532	29158126.29	17.18909243	0.003207845	0.00314072
7	6/10/2021	29274823	29229396.43	17.19224999	0.003157554	0.00301434
8	6/11/2021	29359155	29300840.77	17.19512655	0.002876561	0.00288796
9	6/12/2021	29439989	29372459.74	17.19787605	0.002749499	0.00276158
10	6/13/2021	29510410	29444253.77	17.20026521	0.002389164	0.0026352
11	6/14/2021	29570881	29516223.28	17.20231226	0.002047046	0.00250882
12	6/15/2021	29633105	29588368.7	17.20441428	0.002102023	0.00238244
13	6/16/2021	29700313	29660690.47	17.20667972	0.002265437	0.00225606
14	6/17/2021	29762793	29733189.01	17.20878119	0.002101473	0.00212968
15	6/18/2021	29823546	29805864.75	17.21082035	0.002039161	0.0020033
16	6/19/2021	29881772	29878718.13	17.2127708	0.001950448	0.00187692
17	6/20/2021	29935221	29951749.59	17.21455788	0.001787086	0.00175054
18	6/21/2021	29977861	30024959.55	17.21598128	0.001423397	0.00162416
19	6/22/2021	30028709	30098348.46	17.21767603	0.001694749	0.00149778
20	6/23/2021	30082778	30171916.75	17.21947499	0.001798959	0.0013714

Table 10. For part 9

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	6/24/2021	30134445	30151259.42	17.22119101	0.001716022	0.00162036
2	6/25/2021	30183143	30193504.25	17.22280573	0.001614721	0.00159872
3	6/26/2021	30233183	30235808.27	17.22446224	0.001656507	0.00157708
4	6/27/2021	30279331	30278171.55	17.22598748	0.00152524	0.00155544
5	6/28/2021	30316897	30320594.2	17.22722736	0.00123988	0.0015338
6	6/29/2021	30362848	30363076.28	17.2287419	0.001514543	0.00151216
7	6/30/2021	30411634	30405617.88	17.23034738	0.001605478	0.00149052
8	7/1/2021	30458251	30448219.09	17.23187908	0.001531695	0.00146888
9	7/2/2021	30502362	30490879.99	17.23332627	0.001447198	0.00144724
10	7/3/2021	30545433	30533600.66	17.23473733	0.00141106	0.0014256
11	7/4/2021	30585229	30576381.18	17.23603933	0.001301999	0.00140396
12	7/5/2021	30619932	30619221.65	17.23717332	0.00113399	0.00138232
13	7/6/2021	30663665	30662122.14	17.23860056	0.001427235	0.00136068
14	7/7/2021	30709557	30705082.73	17.24009606	0.001495507	0.00133904
15	7/8/2021	30752950	30748103.52	17.24150808	0.001412016	0.0013174
16	7/9/2021	30795716	30791184.58	17.24289775	0.001389666	0.00129576
17	7/10/2021	30837222	30834326.01	17.24424462	0.001346878	0.00127412
18	7/11/2021	30874376	30877527.88	17.24544874	0.001204118	0.00125248
19	7/12/2021	30907282	30920790.28	17.24651398	0.001065236	0.00123084
20	7/13/2021	30946147	30964113.29	17.24777066	0.001256682	0.0012092

Table 11. For part 10

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	7/14/2021	30987880	30983324.57	17.24911832	0.001347661	0.001235893
2	7/15/2021	31026829	31021978.29	17.25037444	0.001256122	0.001236785
3	7/16/2021	31064908	31060680.25	17.25160098	0.001226541	0.001237678
4	7/17/2021	31106065	31099430.48	17.25292498	0.001323995	0.001238571
5	7/18/2021	31144229	31138229.06	17.25415113	0.001226148	0.001239464
6	7/19/2021	31174322	31177076.04	17.25511691	0.000965781	0.001240356
7	7/20/2021	31216337	31215971.49	17.25646375	0.001346837	0.001241249
8	7/21/2021	31257720	31254915.46	17.25778855	0.001324807	0.001242142
9	7/22/2021	31293062	31293908.02	17.25891858	0.001130027	0.001243034
10	7/23/2021	31293062	31332949.22	17.25891858	0*	0.001243927
11	7/24/2021	31371901	31372039.13	17.26143479	0.00251621	0.00124482
12	7/25/2021	31411262	31411177.8	17.26268866	0.001253872	0.001245712
13	7/26/2021	31440951	31450365.31	17.26363339	0.000944725	0.001246605
14	7/27/2021	31484605	31489601.7	17.26502087	0.001387482	0.001247498
15	7/28/2021	31528114	31528887.04	17.26640183	0.00138096	0.001248391
16	7/29/2021	31572344	31568221.39	17.26780372	0.001401893	0.001249283
17	7/30/2021	31613993	31607604.82	17.26912201	0.001318292	0.001250176
18	7/31/2021	31655824	31647037.38	17.27044432	0.001322306	0.001251069
19	8/1/2021	31695958	31686519.13	17.27171134	0.001267021	0.001251961
20	8/2/2021	31726507	31726050.14	17.27267469	0.00096335	0.001252854

*This value is zero because of not reporting of data on this day.

Table 12. For part 11

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	8/3/2021	31769132	31787365	17.2740173	0.001342613	0.00132
2	8/4/2021	31812114	31822809.47	17.27536934	0.001352035	0.0013
3	8/5/2021	31856757	31858293.47	17.27677169	0.001402351	0.00128
4	8/6/2021	31895385	31893817.04	17.27798351	0.001211819	0.00126
5	8/7/2021	31934455	31929380.21	17.2792077	0.001224193	0.00124
6	8/8/2021	31969954	31964983.04	17.28031871	0.001111004	0.00122
7	8/9/2021	31998158	32000625.57	17.28120052	0.000881815	0.0012
8	8/10/2021	32036511	32036307.84	17.2823984	0.001197883	0.00118
9	8/11/2021	32077706	32072029.9	17.28368346	0.001285051	0.00116
10	8/12/2021	32117826	32107791.79	17.28493339	0.001249932	0.00114
11	8/13/2021	32156493	32143593.56	17.28613658	0.001203188	0.00112
12	8/14/2021	32192576	32179435.25	17.28725805	0.001121478	0.0011
13	8/15/2021	32225513	32215316.9	17.28828065	0.001022602	0.00108
14	8/16/2021	32250679	32251238.57	17.28906128	0.00078063	0.00106
15	8/17/2021	32285857	32287200.29	17.29015146	0.001090174	0.00104
16	8/18/2021	32322258	32323202.1	17.29127828	0.001126825	0.00102
17	8/19/2021	32358829	32359244.06	17.29240909	0.001130811	0.001
18	8/20/2021	32393286	32395326.21	17.29347337	0.001064275	0.00098
19	8/21/2021	32424234	32431448.6	17.2944283	0.000954928	0.00096
20	8/22/2021	32449306	32467611.26	17.29520125	0.000772951	0.00094

Table 13. For part 12

Day	Date	Total Confirmed (Actual) C(t)	Total Confirmed (Predicted) C(t)	log C(t)	Δlog C(t) (Actual)	Δlog C(t) (Predicted)
1	8/23/2021	32474773	32486002.94	17.29598576	0.000784517	0.00129
2	8/24/2021	32512366	32526387.42	17.2971427	0.001156938	0.00128
3	8/25/2021	32558530	32566822.1	17.29856159	0.001418884	0.00127
4	8/26/2021	32603188	32607307.05	17.29993227	0.001370683	0.00126
5	8/27/2021	32649947	32647842.32	17.30136543	0.001433158	0.00125
6	8/28/2021	32695030	32688427.99	17.30274528	0.001379847	0.00124
7	8/29/2021	32737939	32729064.11	17.30405682	0.001311542	0.00123
8	8/30/2021	32768880	32769750.75	17.30500148	0.000944666	0.00122
9	8/31/2021	32810845	32810487.97	17.3062813	0.001279817	0.00121
10	9/1/2021	32857937	32851275.82	17.30771553	0.001434229	0.0012
11	9/2/2021	32903289	32892114.39	17.30909482	0.001379294	0.00119
12	9/3/2021	32945907	32933003.72	17.31038924	0.001294413	0.00118
13	9/4/2021	32988673	32973943.88	17.31168646	0.001297226	0.00117
14	9/5/2021	33027621	33014934.93	17.31286641	0.001179952	0.00116
15	9/6/2021	33058843	33055976.95	17.3138113	0.000944884	0.00115
16	9/7/2021	33096718	33097069.98	17.31495633	0.001145029	0.00114
17	9/8/2021	33139981	33138214.1	17.31626264	0.001306316	0.00113
18	9/9/2021	33174954	33179409.36	17.3173174	0.001054756	0.00112
19	9/10/2021	33208330	33220655.84	17.31832296	0.001005555	0.00111
20	9/11/2021	33236921	33261953.59	17.31918354	0.000860589	0.0011

Table 14. Predicted values of Δlog C(t) part wise

Day	Part 1	Part 2	Part 3	Part 4	Part 5	Part 6
1	0.001438788	0.001149274	0.001516324	0.002529965	0.007674152	0.020599321
2	0.001435395	0.00108369	0.001499476	0.003131019	0.009081735	0.018485747
3	0.00130508	0.001114477	0.001489199	0.003456103	0.009855293	0.020258556
4	0.000950194	0.001092199	0.001510775	0.00355039	0.01015573	0.020857033
5	0.001304784	0.000840193	0.001396734	0.003787276	0.011070052	0.020817205
6	0.001437672	0.001019734	0.001105018	0.004039636	0.011510057	0.021198529
7	0.001369825	0.001189435	0.001346477	0.003489931	0.012564982	0.020272578
8	0.001340789	0.000855926	0.001561417	0.004035899	0.011884999	0.018644538
9	0.001394652	0.001115401	0.001508061	0.004546982	0.013378298	0.017773704
10	0.001238425	0.001118835	0.001634997	0.005002767	0.014365235	0.018665581
11	0.000852864	0.001067662	0.001674253	0.005241567	0.015324946	0.019761432
12	0.001187756	0.000835169	0.001657652	0.005252327	0.016287949	0.01946023
13	0.001090754	0.001062068	0.001369395	0.005665692	0.017834185	0.018490096
14	0.001760404	0.001177019	0.001592449	0.004657964	0.018345838	0.018258784
15	0.001219587	0.001204094	0.00202712	0.004411607	0.017060551	0.016303973
16	0.001214565	0.001275525	0.002061132	0.005935765	0.019081758	0.014453939
17	0.001063628	0.001298556	0.002197809	0.006643591	0.019948369	0.01504001
18	0.000802366	0.001290966	0.00223155	0.007218306	0.020682627	0.015420873
19	0.00102481	0.000961209	0.00231187	0.007496613	0.021098573	0.014372638
20	0.001196154	0.001246633	0.002148879	0.008260053	0.020833904	0.01346985
Average	0.001231425	0.001099903	0.001692029	0.004917673	0.014901962	0.018130231

Table 15. Predicted values of Δlog C(t) part wise

Day	Part 7	Part 8	Part 9	Part 10	Part 11	Part 12
1	0.012686242	0.004209215	0.001716022	0.001347661	0.001342613	0.000784517
2	0.011335017	0.003980933	0.001614721	0.001256122	0.001352035	0.001156938
3	0.010500585	0.003487088	0.001656507	0.001226541	0.001402351	0.001418884
4	0.010540559	0.002987513	0.00152524	0.001323995	0.001211819	0.001370683
5	0.010771191	0.003188268	0.00123988	0.001226148	0.001224193	0.001433158
6	0.010020508	0.003207845	0.001514543	0.000965781	0.001111004	0.001379847
7	0.009835434	0.003157554	0.001605478	0.001346837	0.000881815	0.001311542
8	0.009119518	0.002876561	0.001531695	0.001324807	0.001197883	0.000944666
9	0.008344808	0.002749499	0.001447198	0.001130027	0.001285051	0.001279817
10	0.007315575	0.002389164	0.00141106	0*	0.001249932	0.001434229
11	0.007722604	0.002047046	0.001301999	0.00251621	0.001203188	0.001379294
12	0.007750275	0.002102023	0.00113399	0.001253872	0.001121478	0.001294413
13	0.006786213	0.002265437	0.001427235	0.000944725	0.001022602	0.001297226
14	0.006287117	0.002101473	0.001495507	0.001387482	0.00078063	0.001179952
15	0.005952591	0.002039161	0.001412016	0.00138096	0.001090174	0.000944884
16	0.005460426	0.001950448	0.001389666	0.001401893	0.001126825	0.001145029
17	0.004535911	0.001787086	0.001346878	0.001318292	0.001130811	0.001306316
18	0.004701897	0.001423397	0.001204118	0.001322306	0.001064275	0.001054756
19	0.004727921	0.001694749	0.001065236	0.001267021	0.000954928	0.001005555
20	0.004643032	0.001798959	0.001256682	0.00096335	0.000772951	0.000860589
Average	0.007951871	0.002572171	0.001414784	0.001245202	0.001126328	0.001199115

*This value is zero because of not reporting of data on this day.

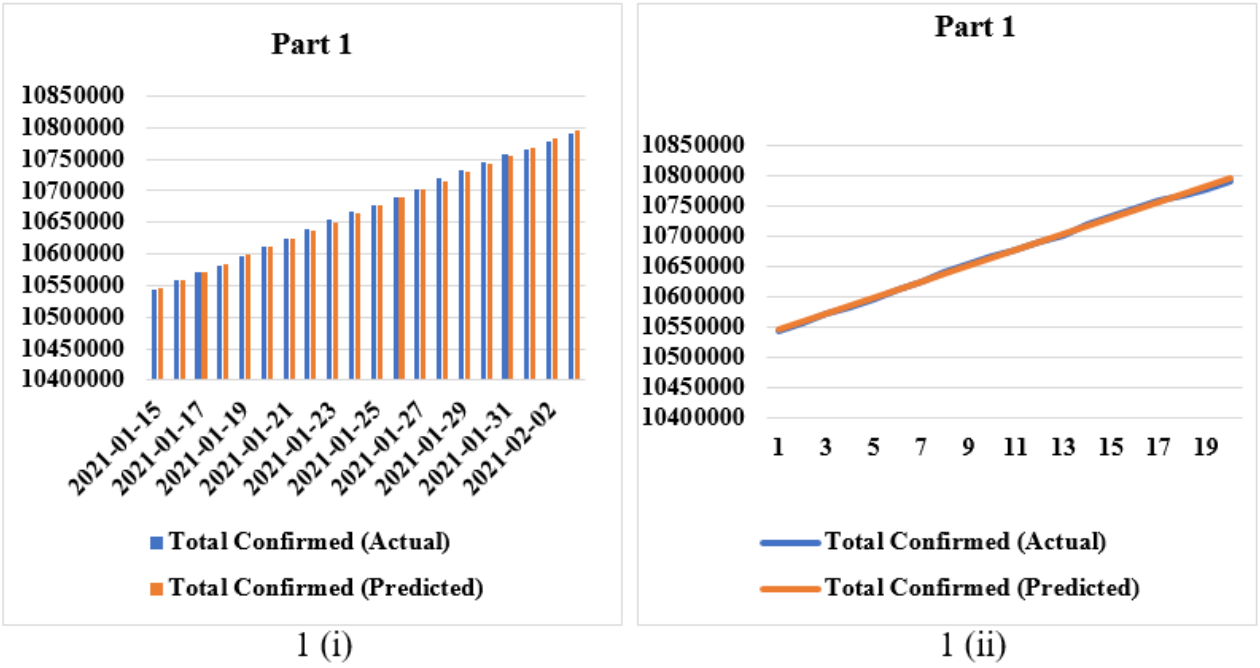


Fig 1. Total confirmed actual and predicted value for part 1.

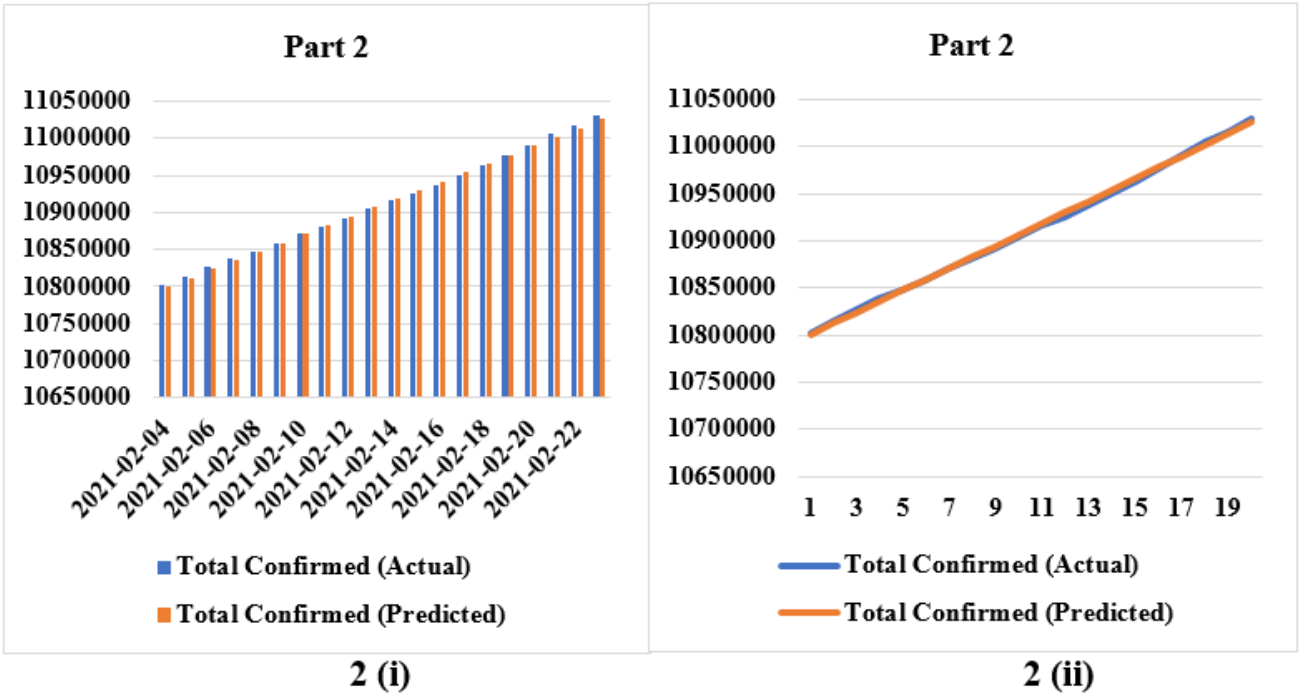


Fig 2. T otal confirmed actual and predicted value for part 2

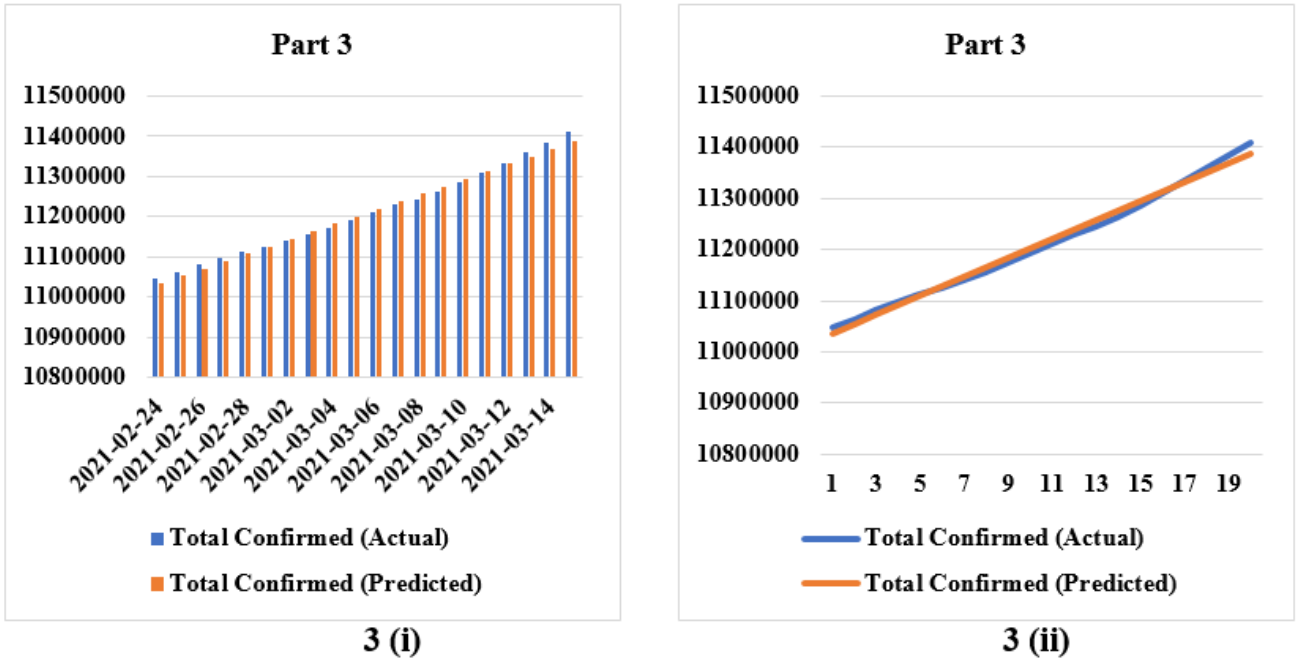


Fig 3. T otal confirmed actual and predicted value for part 3

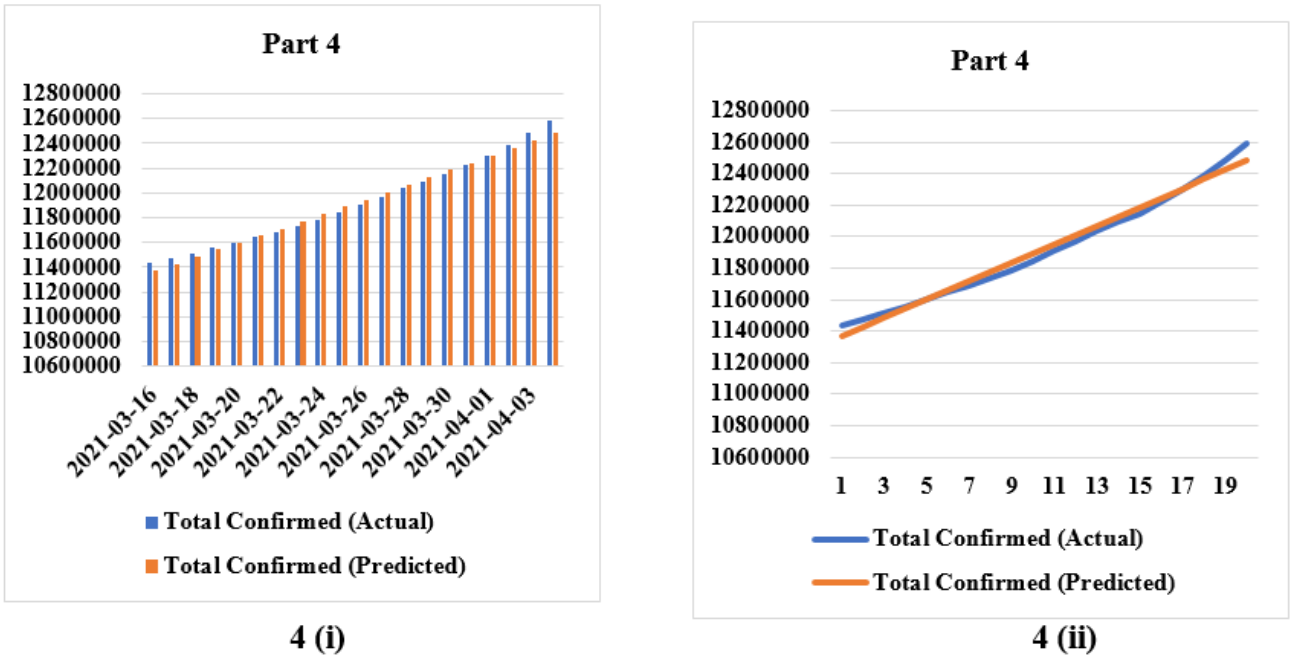
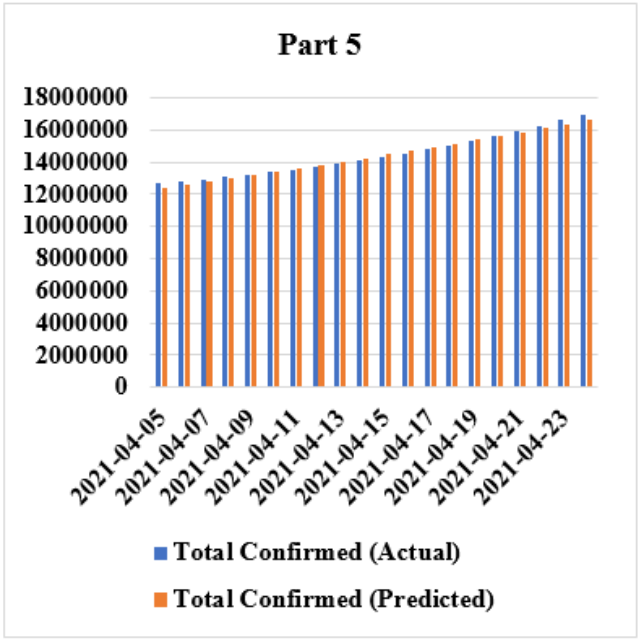


Fig 4. T otal confirmed actual and predicted value for part 4



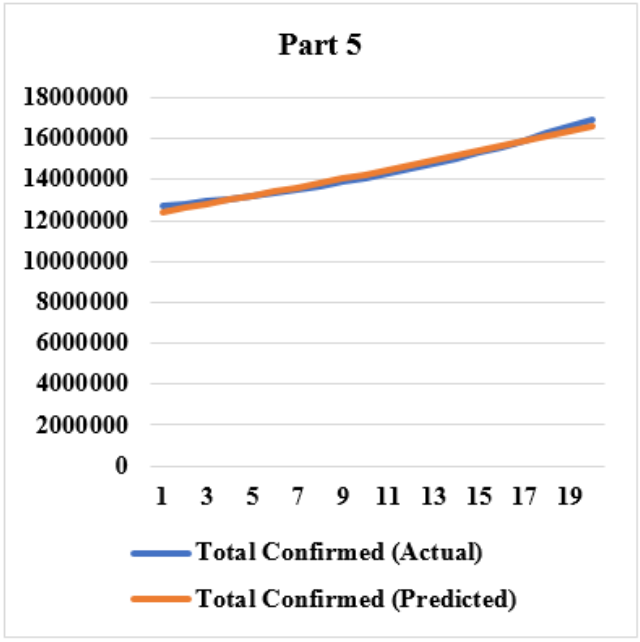
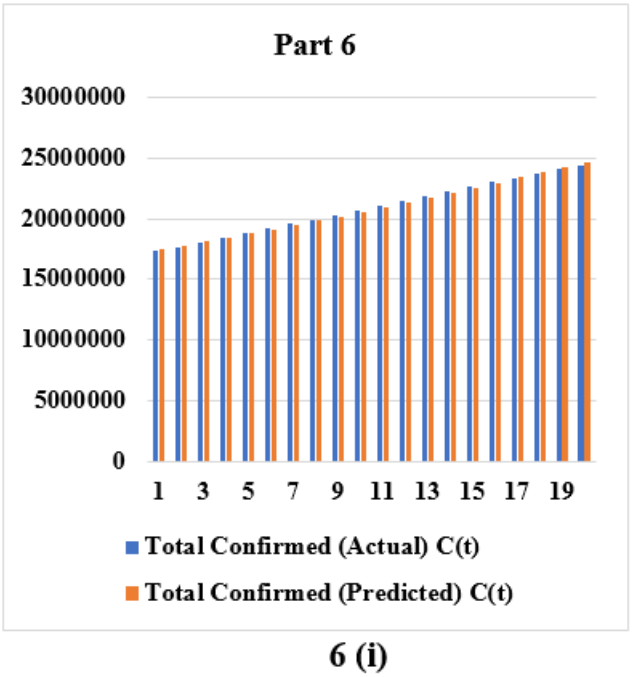


Fig 5. T otal confirmed actual and predicted value for part 5



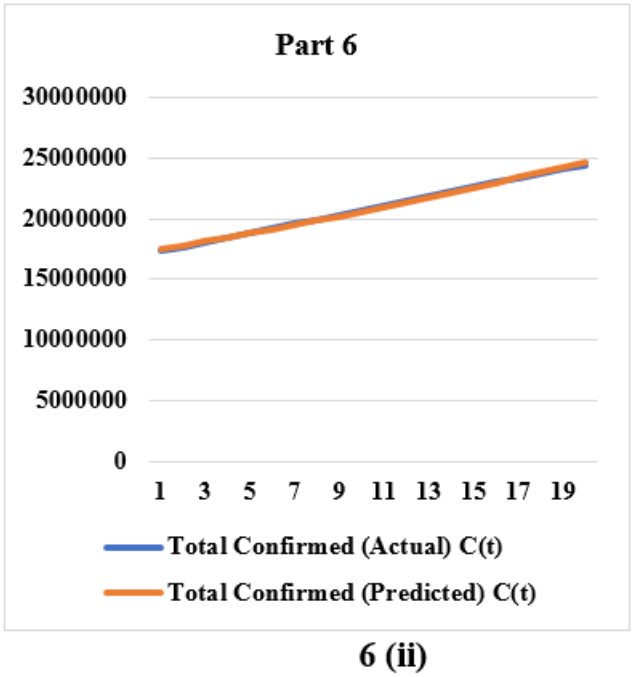


Fig 6. Total confirmed actual and predicted value for part 6

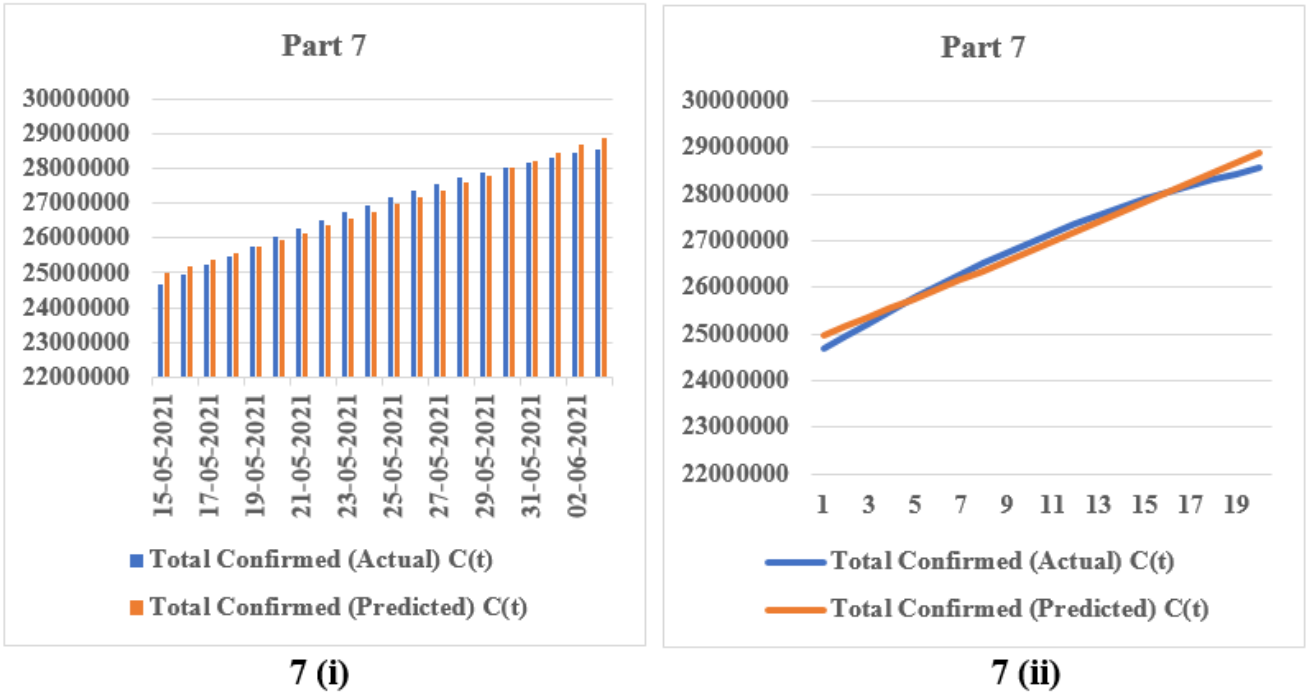


Fig 7. Total confirmed actual and predicted value for part 7

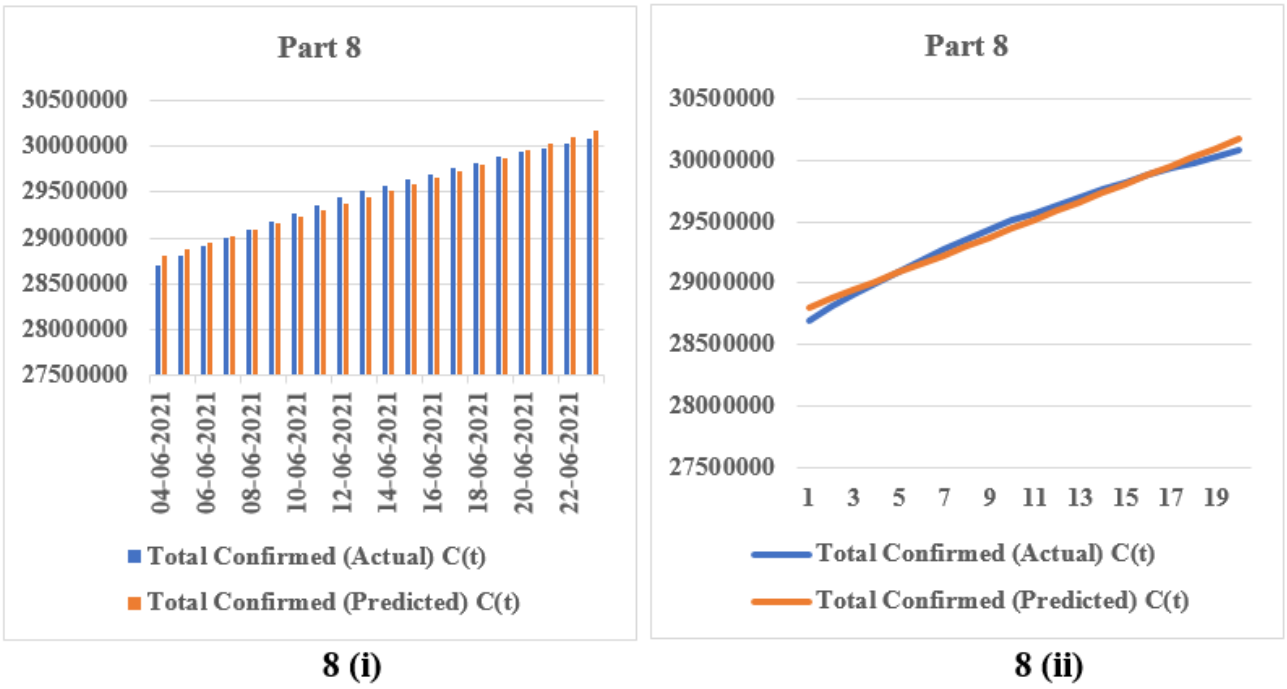


Fig 8. Total confirmed actual and predicted value for part 8

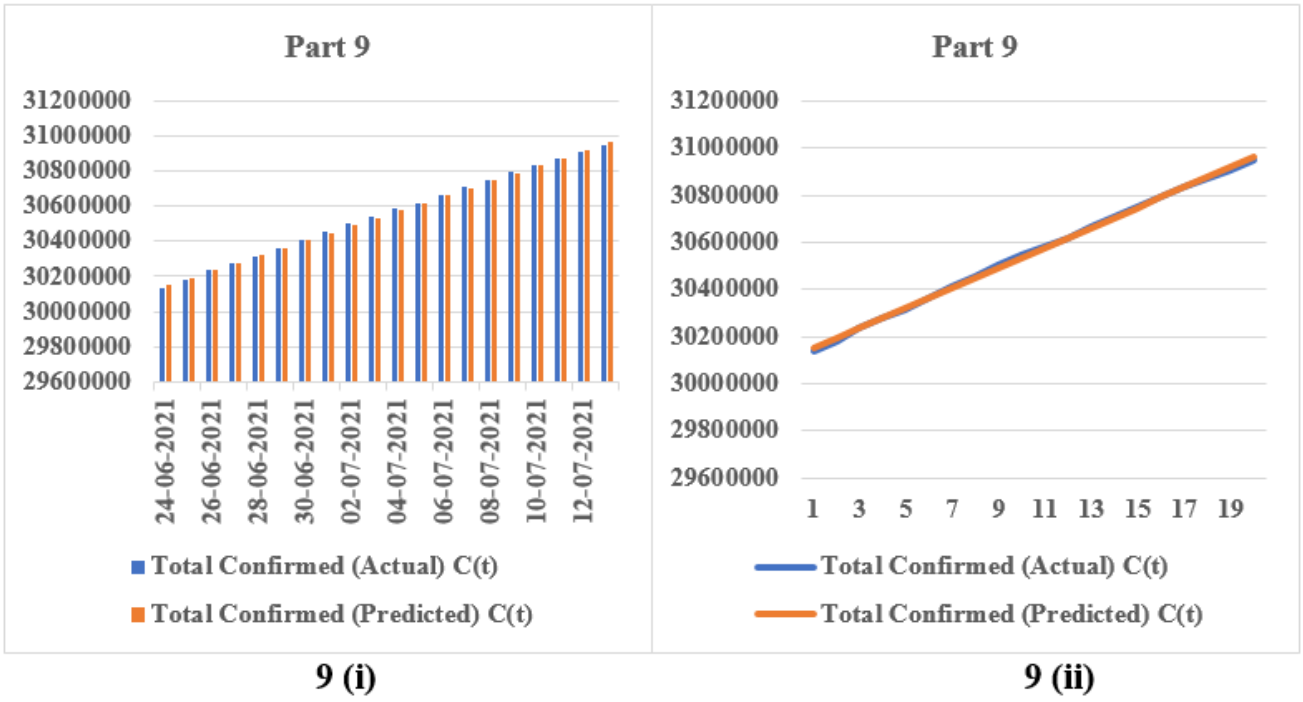


Fig 9. Total confirmed actual and predicted value for part 9

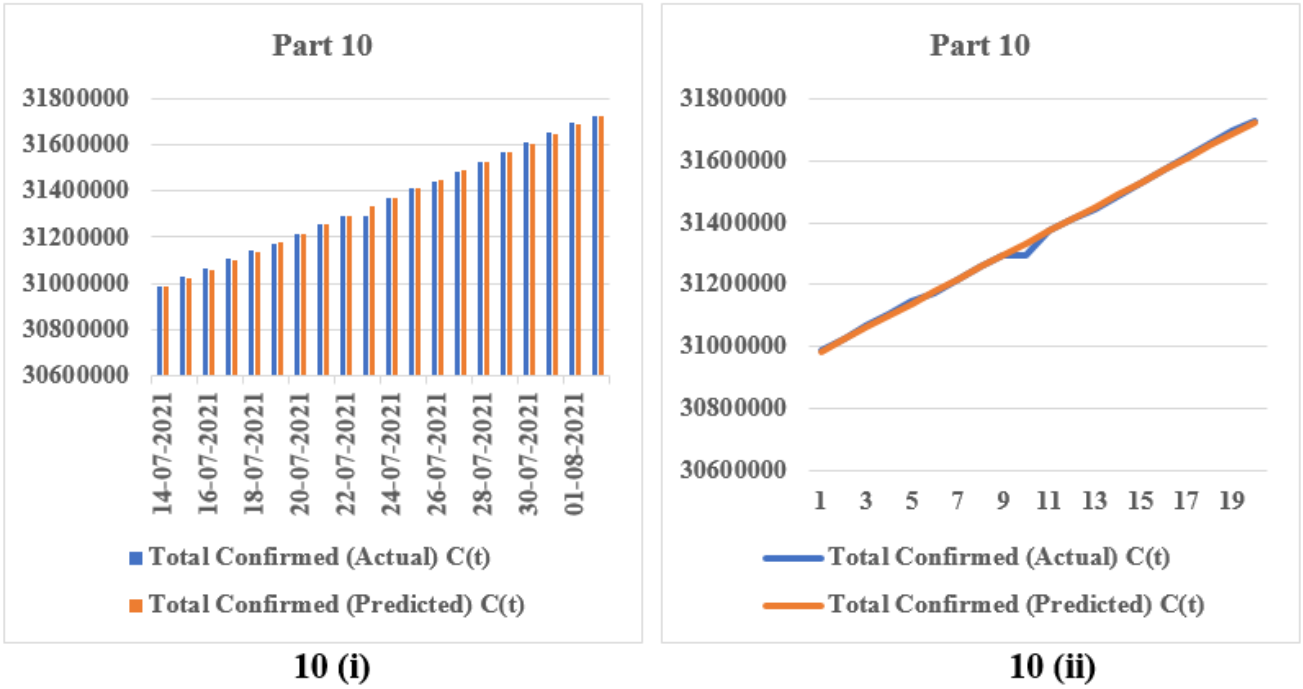


Fig 10. Total confirmed actual and predicted value for part 10

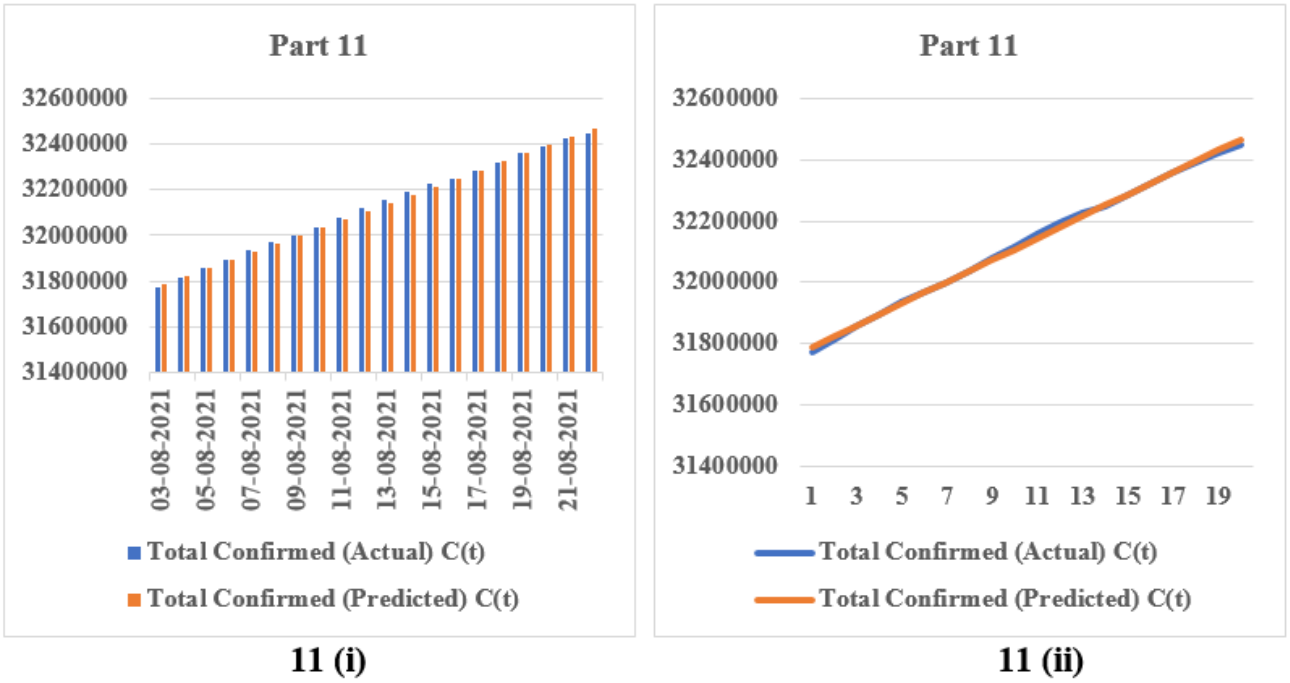


Fig 11. Total confirmed actual and predicted value for part 11

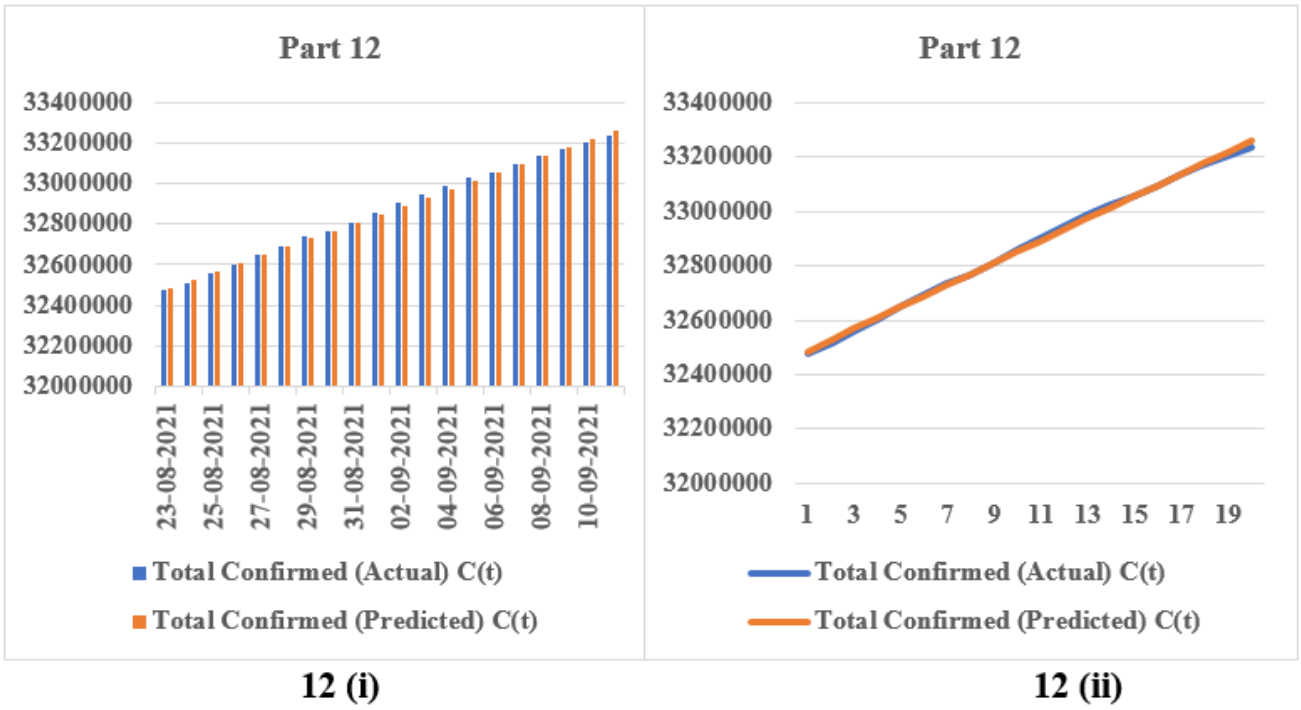


Fig 12. Total confirmed actual and predicted value for part 12

Table 16. The linear equation and correlation coefficient of each part

Part	Duration	Δlog C(t) =A+B*t	correlation coefficient (r)	r square
1	2021-01-15 to 2021-02-03	Δlog C(t) =0.00139-0.000015138*t	-0.395	0.156025
2	2021-02-04 to 2021-02-23	Δlog C(t)=0.001+0.00000008*t	0.36	0.1296
3	2021-02-24 to 2021-03-15	Δlog C(t)=0.00119+0.000047*t	0.81	0.6561
4	2021-03-16 to 2021-04-04	Δlog C(t)=0.002348+0.0002446*t	0.93	0.8649
5	2021-04-05 to 2021-04-24	Δlog C(t)=0.00730+0.0007*t	0.99	0.9801
6	2021-04-25 to 2021-05-14	Δlog C(t)=0.02189-0.000358*t	-0.86	0.7396
7	2021-05-15 to 2021-06-03	Δlog C(t)=0.01239-0.0004233*t	-0.98	0.9604
8	2021-06-04 to 2021-06-23	Δlog C(t)=0.003899-0.000126*t	-0.95	0.9025
9	2021-06-24 to 2021-07-13	Δlog C(t)=0.00164-0.0000216*t	-0.73	0.5329
10	2021-07-14 to 2021-08-02	Δlog C(t)=0.001235+0.0000008927*t	0.01	0.0001
11	2021-08-03 to 2021-08-22	Δlog C(t)=0.00134-0.00002*t	-0.68	0.4624
12	2021-08-23 to 2021-09-11	Δlog C(t)=0.0013-0.00001*t	-0.3	0.09

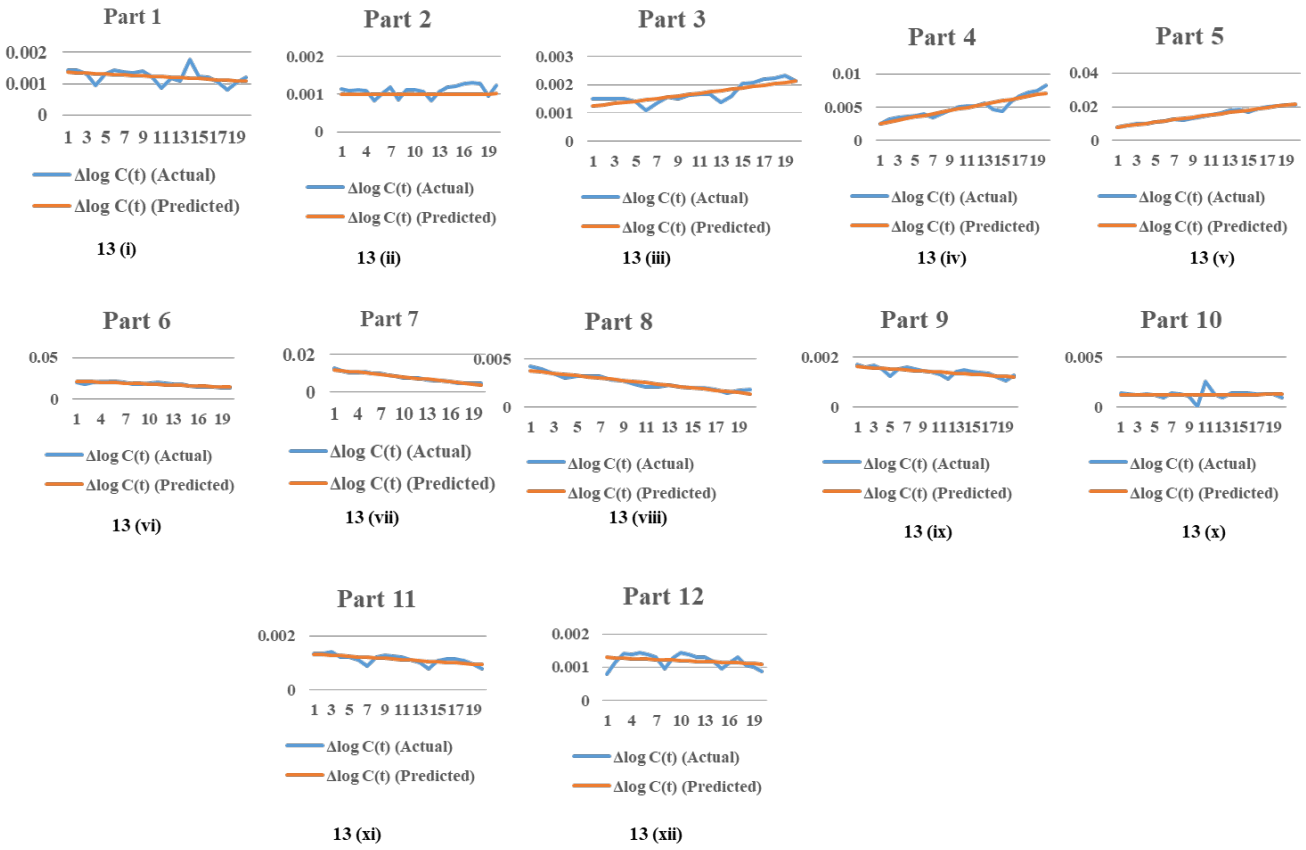


Fig 13. Comparison of the actual and predicted values of Δlog C(t)

Figure 13 (ii) indicates that there is a suddenly increasing linear trend between these two values. It means the exponential growth curve remained exponential.

Figure 13 (iii) demonstrates that this increasing linear trend remains increasing and has not started to decrease again.

Figure 13 (iv) implies that there is more strong, increasing linear trend between these two values, we conclude that the exponential growth curve of total confirmed cases being continued in this phase also, and maybe remain continue in the next phase.

Figure 13 (v) reflects that there is a more powerful increasing linear trend between these two values. It implies that these values are almost coinciding with each other. In this part, the exponential curve of total confirmed cases continued to be exponential and there is no chance to convert it into a logarithmic curve for some time.

Figure 13 (vi) , 13 (vii) and 13 (viii) reflect that there is a powerful decreasing linear trend between these two values. This part indicates that the change from exponential to logarithmic is about to start.

Figure 13 (ix) depicts that this powerful decreasing in Δlog C(t) is slightly become weak.

Figure 13 (x) and 13 (xii) depicts that there is no linear relationship between t and Δlog C(t).

Now, We apply the statistical tests at the 5 % significance with the degree of freedom 18, to the null assumption that there is no significance linear relationship between Δlog C(t) and 't', against the two-tailed alternative assumption that there is a significant linear correlation between the variables Δlog C(t) and 't' referred to the equations in table 16 of each part separately. The two-tailed hypothetical value of 't' is 2.101. Now, we apply the student t-test in each part to check the validity of our hypothesis, we summarize the values in the table 17. Student 't' value for each part is calculated by the formula,

$$t^2 = \frac{(n-2)\,r^2}{1-r^2} \tag{3}$$

Where n = 20 and r represent the linear correlation coefficient between Δlog C(t) and t.

Table 17. t-test statistics for each part

Part	Duration	Correlation coefficient r	r square	Student t-test calculated value
1	2021-01-15 to 2021-02-03	-0.395	0.156025	3.328
2	2021-02-04 to 2021-02-23	0.363	0.131769	2.732
3	2021-02-24 to 2021-03-15	0.81	0.6561	34.341
4	2021-03-16 to 2021-04-04	0.928	0.861184	111.669
5	2021-04-05 to 2021-04-24	0.99	0.9801	886.523
6	2021-04-25 to 2021-05-14	-0.864	0.746496	53.005
7	2021-05-15 to 2021-06-03	-0.985	0.970225	586.535
8	2021-06-04 to 2021-06-23	-0.95	0.9025	166.616
9	2021-06-24 to 2021-07-13	-0.727	0.528529	20.179
10	2021-07-14 to 2021-08-02	0.012	0.000144	0.003
11	2021-08-03 to 2021-08-22	-0.682	0.465124	15.653
12	2021-08-23 to 2021-09-11	-0.3	0.09	1.781

In part 10 and part 12 the calculated value of t are 0.003 and 1.781 respectively, which is less than the hypothetical value of 2.101. Surely more than 5%, the null assumption is true. Thus, we deduce that the linearity between Δlog C(t) and 't' is not significant. This is identical to deciding that the coefficients of the regression (-0.0000008 and -0.00001 respectively) do not significantly differ from zero. It means the exponential growth may continue in upcoming days.

For part 1-9 and part 11, the observed value of t are more than the hypothetical value of t = 2.101. Thus, we deduce that the null assumption is to be dismissed for these parts, and there is a meaningful linear relationship exists between Δlog C(t) and 't. The regression coefficients in these parts reasonably differ from zero.

Figure 14 (i) and 14 (ii) is a graphical representation of COVID-19 total confirmed cases till the 12th September 2021 in the linear and the logarithmic scale respectively. Both the figures represent the same data, but flattened of logarithmic curve display the clearest picture of COVID-19 cases with respect to different prevention measures. At the flatten point of a logarithmic scale the public health measures begin to produce the desired effect and result. The logarithmic chart will highlight any substantial changes in the trend-whether it is up or down. Because of the way the scale is compressed, the logarithmic diagram shows the lines flattened earlier as compared to the linear scale. using logarithmic scale is better than as compare to linear scale. The interpretation of working of different prevention measures and vaccination can be seen in the epidemic curve on the logarithmic scale easily.

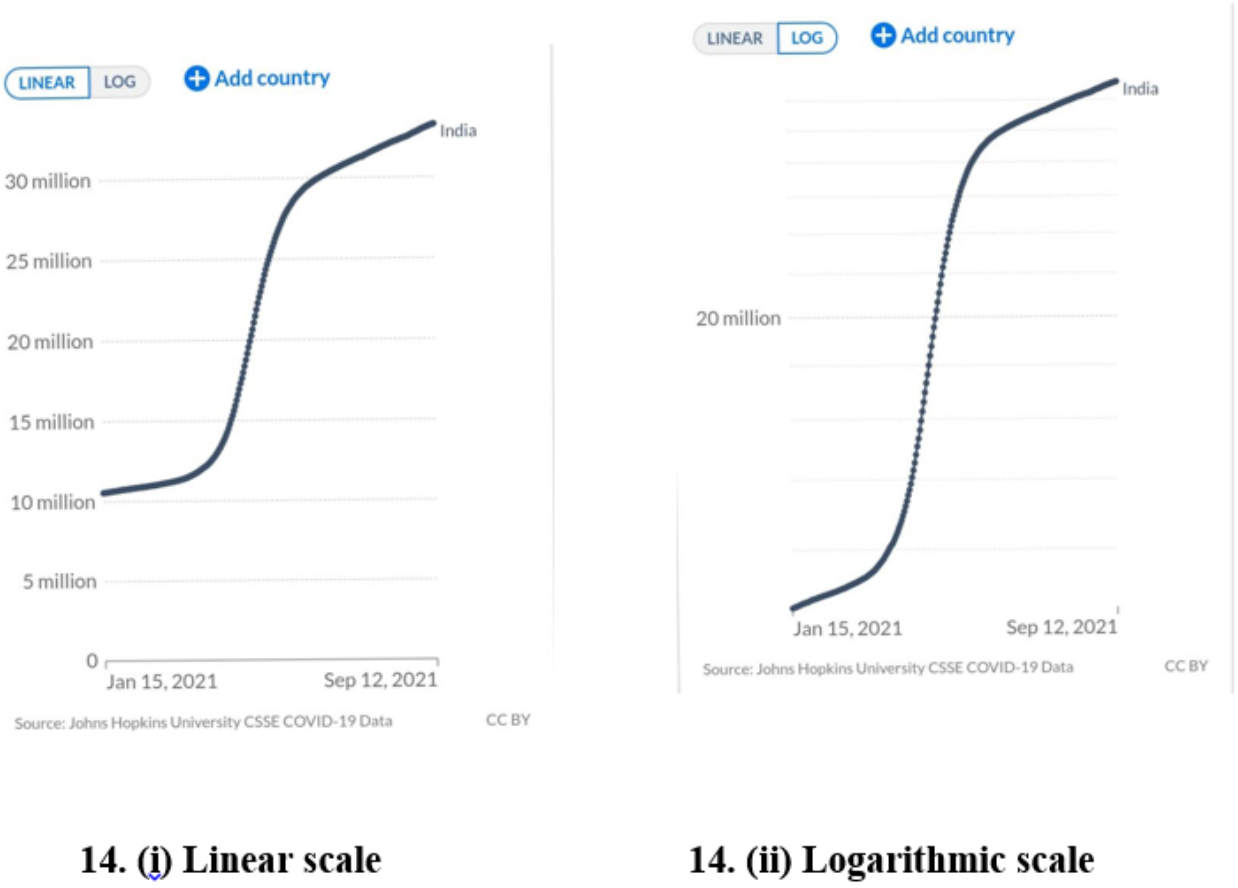


Fig 14. Linear and logarithmic scales of cumulative confirmed cases in India for the same duration. Source: Johns Hopkins University, CSSE COVID-19 data.

4 Conclusion

In this paper, we analyzed the total confirmed COVID-19 data for 240 days from 15th January to 11th September 2021, by dividing it into 12 equal parts. We have shown that during these periods the total confirmed cases followed an almost exponential growth in India. We have shown that the exponential growth curve changes into logarithmic or not, as the value of $\Delta \log C(t)$ tend to zero or not. We performed the statistical significance test and concluded that there is a strong positive linear relationship between $\Delta \log C(t)$ and time 't'. As per current government guidelines on COVID-19 (Janata curfew, social distancing, wearing a mask, vaccination, etc.), It will take about 127 days from August 23, 2021 to change the cumulative confirmed case pattern from exponential to logarithmic, and has begun to flatten. In the context of India, our research demonstrates the importance of graphical presentation of COVID-19 data and compares between the logarithmic and linear scale. The Flattening of the logarithmic curve indicates that the prevention measures are working well to stop the spread of infectious diseases.

5 Acknowledgements

We express our sincere gratitude to the editor and the reviewers to improve the quality of research study by their useful suggestions.

Mathematics Subject Classification-2010 : 97Mxx, 97K70.

References

1) Azad S, Poonia N. Short-term forecasts of COVID-19 spread across Indian states until 29 May 2020 under the worst-case scenario. 2020. doi:10.20944/preprints202004.0491.v1.
2) Poonia N, Azad S. Short-term forecasts of COVID-19 spread across Indian states until 1 May 2020. *arXiv preprint*. 2020. Available from: https://arxiv.org/pdf/2004.13538.
3) Pandey G, Chaudhary P, Gupta R, Pal S. SEIR and Regression Model based COVID-19 outbreak predictions in India. *arXiv preprint*. 2020. Available from: https://arxiv.org/pdf/2004.00958.
4) Rai B, Shukla A, Dwivedi LK. COVID-19 in India: Predictions, Reproduction Number and Public Health Preparedness. *MedRxiv*. 2020. Available from: https://doi.org/10.1101/2020.04.09.20059261.
5) Bedi P, Dhiman S, Gole P, Gupta N, Jindal V. Prediction of COVID-19 Trend in India and Its Four Worst-Affected States Using Modified SEIRD and LSTM Models. *SN Computer Science*. 2021;2(3):16. Available from: https://dx.doi.org/10.1007/s42979-021-00598-5.
6) Pandey A, Prakash A, Agur R, Maruvada G. Determinants of COVID-19 pandemic in India: an exploratory study of Indian states and districts. *Journal of Social and Economic Development*. 2021;23(S2):248–279. Available from: https://dx.doi.org/10.1007/s40847-021-00154-0.
7) Chu J. A statistical analysis of the novel coronavirus (COVID-19) in Italy and Spain. *PLOS ONE*. 2021;16(3):e0249037. Available from: https://dx.doi.org/10.1371/journal.pone.0249037.
8) Baruah HK. A Numerical Study of the Current COVID-19 Spread Patterns in India, the USA and the World. *MedRxiv*. 2020. Available from: https://doi.org/10.1101/2020.10.05.20206839.
9) Baruah HK. Nearly Perfect Forecasting of the Total COVID-19 Cases in India: A Numerical Approach. *MedRxiv*. 2020. Available from: https://doi.org/10.1101/2020.06.13.20130096.
10) Baruah HK. On Reliability of the COVID-19 Forecasts. *MedRxiv*. 2020. Available from: https://doi.org/10.1101/2020.06.01.20118844.
11) Baruah HK. The Uncertain COVID-19 Spread Pattern in India: A Statistical Analysis of the Current Situation. *MedRxiv*. 2020. Available from: https://doi.org/10.1101/2020.08.30.20184598.
12) https://www.bbc.com/hindi/india-51308206, India today accessed on 30 January 2020. . .
13) https://www.thehindu.com/sci-tech/health/indias-first-covid-19-death-confirmed-in-karnataka-total-number-of-cases-cross-70/article31053153.ece/amp/ . .
14) https://www.worldometers.info/world-population/india-population/ . .
15) Kermack WO, Mckendrick AG. Contributions to the mathematical theory of epidemics. II. —The problem of endemicity. *Proceedings of the Royal Society of London Series A, Containing Papers of a Mathematical and Physical Character*. 1932;138(834):55–83.
16) Kermack WO, Mckendrick AG. Contributions to the mathematical theory of epidemics—III. Further studies of the problem of endemicity. *Bulletin of Mathematical Biology*. 1991;53(1-2):89–118.
17) Kermack WO, Mckendrick AG. Contributions to the mathematical theory of epidemics-II. The problem of endemicity. *Bulletin of mathematical biology*. 1991;53(1-2):80041–80043.
18) Pai C, Bhaskar A, Rawoot V. Investigating the dynamics of COVID-19 pandemic in India under lockdown. *Chaos, Solitons & Fractals*. 2020;138:109988. Available from: https://dx.doi.org/10.1016/j.chaos.2020.109988.
19) Ranjan R. Predictions for COVID-19 outbreak in India using epidemiological models. *MedRxiv*. 2020. Available from: https://doi.org/10.1101/2020.04.02.20051466.
20) Acharya R, Porwal A. A vulnerability index for the management of and response to the COVID-19 epidemic in India: an ecological study. *The Lancet Global Health*. 2020;8(9):e1142–e1151. Available from: https://dx.doi.org/10.1016/s2214-109x(20)30300-4.
21) Li T, Zhang M, Li Y, Lagerspetz E, Tarkoma S, Hui P. The Impact of Covid-19 on Smartphone Usage. *IEEE Internet of Things Journal*. 2021;8(23):16723. Available from: https://dx.doi.org/10.1109/jiot.2021.3073864.
22) Darapaneni N, Das D, Das A, Sivasubramanian V, Paduri AR. Determining the Preparedness of The German Government and Medical Authorities in Handling COVID-19 Crisis. *IJERT*. Available from: https://www.ijert.org/research/determining-the-preparedness-of-the-german-government-and-medical-authorities-in-handling-covid-19-crisis-IJERTCONV9IS02005.pdf.
23) Jahan N, Rubeshkumar P, Karuppiah M, Sambath I, Sendhilkumar M, Ilangovan K, et al. Entry and initial spread of COVID-19 in India: Epidemiological analysis of media surveillance data, India, 2020. *Clinical Epidemiology and Global Health*. 2021;9:347–354. Available from: https://dx.doi.org/10.1016/j.cegh.2020.10.008.
24) Sengupta P, Ganguli B, SenRoy S, Chatterjee A. An analysis of COVID-19 clusters in India. *BMC Public Health*. 2021;21(1):631. Available from: https://dx.doi.org/10.1186/s12889-021-10491-8.
25) https://ourworldindata.org/coronavirus/country/india. .
26) Sevi S, Aviña MM, Péloquin-Skulski G, Heisbourg E, Vegas P, Coulombe M, et al. Logarithmic versus Linear Visualizations of COVID-19 Cases Do Not Affect Citizens' Support for Confinement. *Canadian Journal of Political Science*. 2020;53(2):385–390. Available from: https://dx.doi.org/10.1017/s000842392000030x.