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Forecasting By Time Series Models For Covid-19 Cases In India – A Comparative Study

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ABSTRACT:
The objective of the study is to get a overall understanding of the spread of covid-19 in India overtime. The study has attempted to find the trend of the confirmed, cured and death cases are visualized and also compared for different states in India. Time series models like ARIMA, Exponential, Artificial Neural Network, Moving average method, Root mean square method is used. Finally ARIMA, Exponential and Artificial Neural Network is compared to find which method is best. Based on Root Mean Square value the best fitted model for forecasting future values are selected. Thus a fitted Time Series model is used to forecast a trend line for next 6 months.

Keywords: *Covid, ARIMA, Exponential, ANN, Root Mean Square Error(RMSE*).

INTRODUCTION
Time Series analysis is a specific way of analyzing a sequence of data points collected over a consistent interval of time that shows how the variables changes over the time.

COVID -19:

Corona virus disease proceed at Wuhan city of China in early December 2019 has quickly extensive with confirmed cases in almost every country across the world. The World Health Organization coined COVID-19 and declared the corona virus disease as a pandemic on March 11, 2020. The virus originated in bat and human transmission primarily through direct or indirect contact with the infected person with respiratory droplets- coughs, sneezes.

The COVID–19 symptoms start within or after a week from mild cough, fever to respiratory issues and pneumonia symptoms. But nowadays, the COVID–19 disease has become symptom-free, and a patient does not show any sign of contamination for a few days to a week. COVID-19 indicates that 80 percent of infections are mild or asymptomatic, 15 percent are serious, oxygen-requiring, and 5 percent are critical infections requiring ventilation.

Review of Literature:

N.Kumar et al (2020) modelled the evolution of COVID using ARIMA and Prophet Time Series Forecasting Models. They also evaluated the effectiveness of the model using mean absolute error, root mean square error, root relative squared error, and mean absolute percentage error.

Feiyu Jiang et al (2020) figured out the track of the cumulative confirmed cases and deaths of COVID-19 via a piecewise linear trend model. They also encapsulate the phase transitions of the pestilence growth rate via change-points and further enjoys great understandability due to its semi-parametric nature.

Feng et al (2020) confirmed that machine learning models are the most promising methods to predict forecast with their high accuracy, which is most commonly applied in Artificial Neural Networks (ANN), e.g., Multilayer perceptron neural networks, evolutionary ANN, Generalized Regression Neural Networks (GRNN), and Backpropagation Neural Networks.

Navid Feroze (2020) employed the Bayesian structural time series (BSTS) models to investigate the temporal dynamics of COVID-19 in top five affected countries around the world. They have analyzed the casual impact of lockdown in these countries using intervention analysis under BSTS models.

Adam Golinski (2021) expanded a model framework based upon the statistical attribute of the time series. They have organized the study into three distinct phases. First they predicted that the logistic model performed better during the initial phases. Then in the up swing phase the gamma model is more robust than the beta model. In the last phase the beta model performed better.

Fuad Ahmed Chyon et al (2021) employed an AutoRegressive Integrated Moving Average (ARIMA) model to analyze the temporal dynamics of the worldwide spread of COVID-19 during a particular period of time. They also confirmed that the ARIMA Model in predicting COVID 19 confirmed cases was the right approach to provide data results and accuracy.

Rachasak Somyanonthanakul et al (2022) proposed a combination of techniques using autoregressive integrated moving average (ARIMA), a time series model, and association rule mining (ARM)to identify meaningful prognostic factors and predict the number of cases for efficient COVID-19 crisis management. They also revealed that the ARIMAX model has the potential to predict the number of COVID-19 cases by integrating the most associated prognostic factors determined by ARM technique to the ARIMA model, which could be used for preparation and optimal management of hospital resources during pandemics.

Muhammed Navas Thorakkattle et al (2022) analysed an effective methodology for dissecting the major components of a time series that breaks down the main parts of a time series. Bayesian structural time series (BSTS) and ARIMA (Autoregressive Integrated Moving Average) models were used by the researchers to forecast time series.

Yanxia Xie et al (2022) analysed the data for immediate changes in preterm birth rate during the COVID-19 mitigation period in China, including changes related to the various categories of births/pregnancies along with consequent changes in stillbirth rates. They also examined whether the impacts on preterm births associated with prompt corrective action varied by SES.

Michihiro Satoh et al (2022) clarified the effect of the state of emergency due to the corona virus disease 2019 (COVID-19) pandemic in 2020 and assessed the Blood Pressure changes that resulted.

DATA SOURCE

We have used COVID-19 data published in the website, https://prsindia.org/covid-19/cases. This data source consists of confirmed cases, cured cases and death cases in India from Jan 2021- Dec 2021

OBJECTIVE

To forecast and to fit a best Time Series model by comparing the Root Mean Square Error of COVID-19 data for the year Jan 2021 to Dec 2021.

RESEARCH METHODOLOGY

From the open data source, the Covid -19 data for the year 2021 was extracted. The data is cleaned and transformed into a suitable dataset to work with it. Then the dataset is subdivided into three variables they are, confirmed cases, cured cases and death cases. Though the variables are multivariate in nature, we considered each variable individually (univariate), because under each variable time period (month) is involved. We aimed at forecasting the model for six months that is till June 2022 considering all the states in India.

ARIMA:

We propose an algorithm to perform and evaluated the Auto-Regressive Integrated Moving Average (ARIMA) model for 36 states, covid-19 data in India. First we converted covid-19 data into time series data by using these R-code **ts( ).** In general, the ARIMA process first we evaluated the parameters (p,d,q) then we find Akaike Information Criteria (AIC), Corrected Akaike Information Criterion (AICC) and Bayesian Information Criterion (BIC) values to find the best ARIMA model. Here under ARIMA model AIC, AICC and BIC are considered. Suppose if we get AIC to be the lowest value we can say it is the best ARIMA model. In the same way we consider AICC and BIC also. Here we used the R-code i.e., auto.arima() in which it operates automatically. According to the data given it fits the model which is best. We forecasted 3 variables for next 6 months i.e., from January 2022 to June 2022 and we calculated RMSE values for Confirmed, Death and Cured cases.

PROCEDURE FOR ARIMA MODELING – R CODE:

1. Plot the time series data.
2. Check volatility - Run Box-Cox transformation to stabilize the variance.
3. Check whether data contains seasonality. If yes, two options - whatsoever take seasonal changes or fitting seasonal ARIMA model.
4. If the data are non-stationary: take first differences of the data until the data are stationary.
5. Identify orders of p, d and q by examining the ACF and PACF
6. Try your chosen models and use the AICC/BIC to explore for a better model.
7. Check the residuals from your chosen model by plotting the ACF of the residuals and doing a portmanteau test of the residuals. If they do not look like white noise, try a amended model.
8. Check whether residuals are normally distributed with mean zero and constant variance.
9. Once steps 7 and 8 are completed, calculate forecasts.

ANALYSIS AND INTERPRETATION

Descriptive statistics:

Descriptive statistics are used to describe or summarize the characteristics of a sample or data set, such as a Mean, Median, Standard Deviation, Maximum, Minimum and Range. The following table represent to the values of descriptive statistics for COVID-19 data.

Table 1

Mean	661876.0833	12234.2222	656329.3056
Median	314210.5	5226.5	313552.5
Standard deviation	1058625.008	23127.58668	1052086.161
Maximum	4596865	103311	4527311
Minimum	2677	2	2653
Range	4594188	103309	4524658

CONFIRMED CASES :

Maharashtra:

Confirmed cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 in Maharashtra is peak at the month of April for ARIMA, Exponential smoothing and ANN. We have forecasted for 6 months from Jan2022- June 2022 which is moderate for ARIMA, remains same for Exponential smoothing and below moderate for ANN. In the same way it is found for other states also.

Delhi

Confirmed cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 in Delhi is peak at the month of April for ARIMA, Exponential smoothing and ANN. We have forecasted for 6months from Jan2022- June 2022 which is moderate for ARIMA, below moderate for Exponential smoothing and below moderate for ANN.

Tamil Nadu:

Confirmed cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 in Tamil Nadu is peak at the month of April for ARIMA, Exponential smoothing and ANN. We have forecasted for 6months from Jan2022- June 2022 which is moderate for ARIMA, below moderate for Exponential smoothing and below moderate for ANN.

DEATH CASES

Maharashtra:

Death cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Maharashtra is peak in the month of June for ARIMA, Exponential smoothing and ANN. We have forecasted for 6 months from Jan 2022- June 2022 which is decreased moderate for ARIMA, nearly moderate for Exponential smoothing and increased for ANN.

Delhi:

Death cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Delhi is peak in the month of June for ARIMA, Exponential smoothing and ANN and we have forecasted for 6 months from Jan 2022- June 2022which is decreased for ARIMA, moderate for Exponential smoothing and increased for ANN.

Kerala:

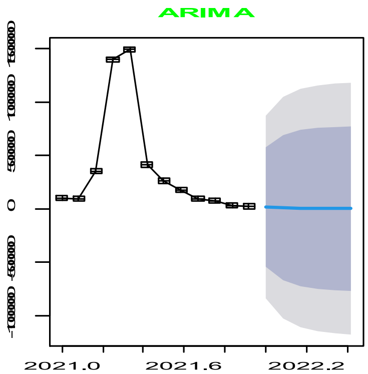
Death cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Kerela is peak in the month of June for ARIMA, Exponential smoothing and ANN. We have forecasted for 6 months from Jan 2022- June 2022which is moderate for ARIMA, moderate for Exponential smoothing and increasing for ANN.

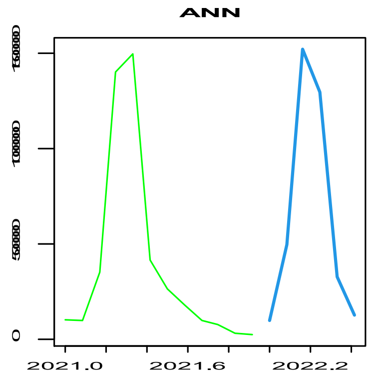
Tamil Nadu:

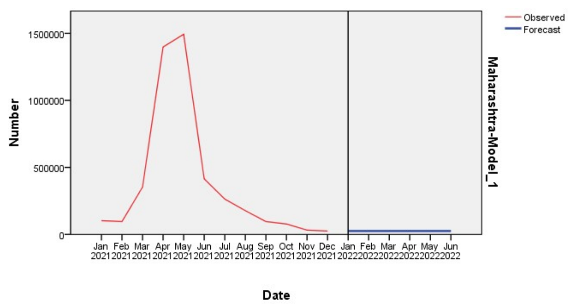
Death cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Tamil Nadu is peak in the month of June for ARIMA, Exponential smoothing and ANN. We have forecasted for 6 months from Jan 2022- June 2022which is moderate for ARIMA, remains the same for Exponential smoothing and below moderate for ANN.

Cured Cases:

Maharashtra:







Cured cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Maharashtra is peak in the month of June for ARIMA, Exponential smoothing and ANN. We have forecasted for 6 months from Jan 2022- June 2022 which is moderate for ARIMA , remains the same for Exponential smoothing and increasing for ANN. In the same way it is calculated for other states also.

DELHI

Cured cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Delhi is peak in the month of June for ARIMA, Exponential smoothing and ANN.We have forecasted for 6 months from Jan 2022- June 2022 which is moderate for ARIMA , remains the same for Exponential smoothing and increasing for ANN.

Kerala:

Cured cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Kerala is peak in the month of June for ARIMA, Exponential smoothing and ANN. We have forecasted for 6 months from Jan 2022- June 2022 which is moderate for ARIMA, nearing to moderate for Exponential smoothing and less than for ANN.

Tamil Nadu:

Cured cases for covid-19 in India from 01 Jan2021 to 31 Dec 2021 of state Tamil Nadu is peak in the month of June for ARIMA, Exponential smoothing and ANN.We have forecasted for 6 months from Jan 2022- June 2022 which is moderate for ARIMA, remains the same for Exponential smoothing and increasing for ANN.

Findings:

SIMPLE EXPONENTIAL SMOOTHING

The simple exponential smoothing model is

where, $f_t = \alpha\, d_{t-1} + (1 - \alpha) f_{t-1},\ 0 < \alpha \le 1$

t =month of the year.

f_t = forecast for the current month.

α = smoothing constant (0.5).

d_{t-1}= most recent months observation.

f_{t-1} = previous month's forecast value

ARTIFICIAL NEURAL NETWORK MODEL

Once an input layer is determined, weights are assigned. These weights help determine the importance of any given variable, with larger ones contributing more significantly to the output compared to other inputs. All inputs are then multiplied by their respective weights and then summed.

The model for ANN is

$w_i x_i + bias = w_1 x_1 + w_2 x_2 + w_3 x_3 + bias$

where,

wi = Weight assigned to the variable.

xi = Input layer.

$bias$ = Extreme limit

The output for the Artificial Neural Network is

$$f(x)=\begin{cases} 1 \; if \; \Sigma w_1 x_1 + b \geq 0 \\ 0 \; if \; \Sigma w_1 x_1 + b < 0 \end{cases}$$

ROOT MEAN SQUARE ERROR(RMSE)

The square root of the sum of square of the deviation of the predicted values from the observed value dividing by their number of observations is known as the Root Mean Square Error. The Root Mean Square error is defined as

$$RMSE = \sqrt{\frac{1}{T}\sum_{i=1}^{T}(Z_{obs} - Z_{pred})^2}$$

CORRELATION • The correlation coefficient (ρ) is a measure that determines the degree to which the movement of two different variables is associated.

$$\boldsymbol{r_{xy}} = \frac{\sum(\boldsymbol{x_i} - \bar{\boldsymbol{x}})(\boldsymbol{y} - \bar{y})}{\sqrt{\sum(\boldsymbol{x_i} - \bar{\boldsymbol{x}})^2 \sum \boldsymbol{y_i} - \bar{y})^2}}$$

• Correlation is used to describe the linear relationship between two continuous variables (e.g., height and weight).

• A correlation value lies between –1 and 1.

PEARSON CORRELATION

The Pearson correlation coefficient measures the strength of the linear association between two variables.

$$r_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x^2 - (\sum x)^2}\sqrt{n\sum y^2 - (\sum y)^2}}$$

r_{xy} = Pearson r correlation coefficient between x and y

n = Number of observations

x_i = Value of x (for i^{th} observation)

y_i = Value of y (for i^{th} observation)

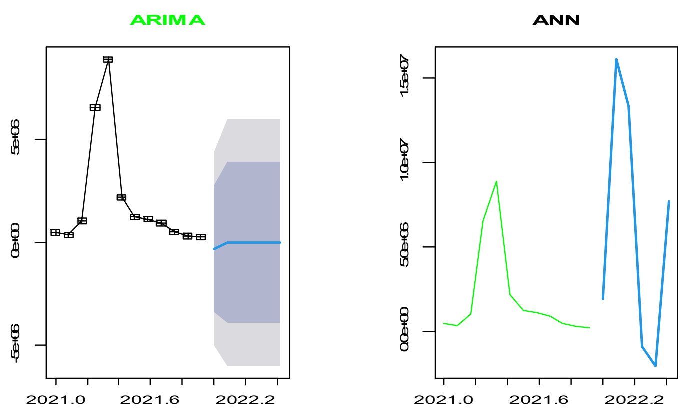
Table 2:Data descriptive of cumulative values:

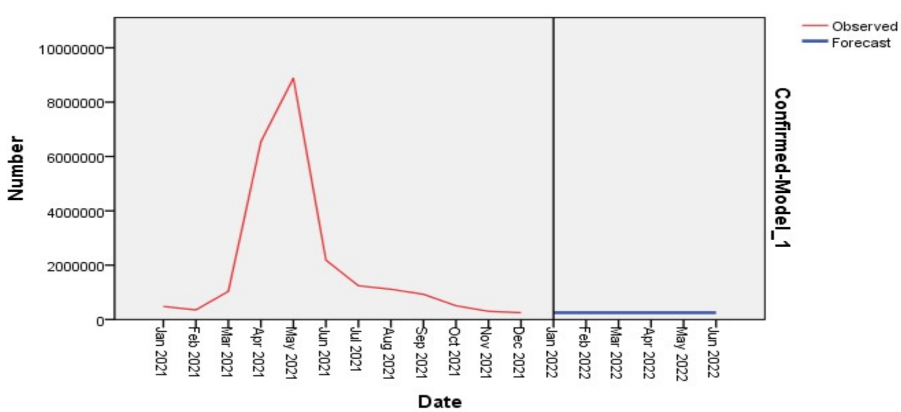
Cases	Confirmed cases	Death cases	Cured cases
January	479570	11278	562845
February	354586	5075	351474
March	1037049	8467	647844
April	6541311	56963	3909735
May	8882565	120145	10007936

June	2187662	78409	3479701
July	1243161	36937	1292988
August	1113056	31182	1139159
September	929135	21768	1021254
October	506593	22583	612698
November	302008	23285	34739
December	250843	24340	252482

CONFIRMED CASES

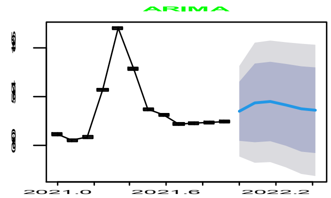
The cumulative graph of confirmed cases in India for six months of forecasting is as follows. In ARIMA and Exponential Smoothing Model the graph resembles as decreasing over six months whereas in ANN Model the data point reaches the peak and drastically decreases.

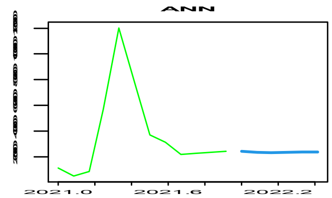


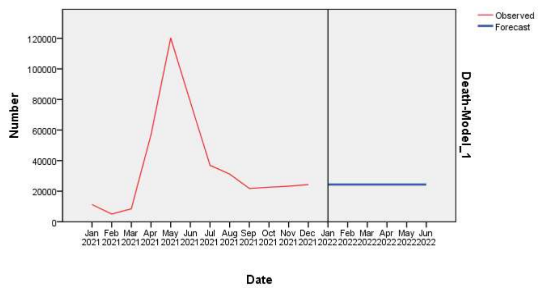


DEATH CASES

The cumulative graph of death cases in India for six months of forecasting is as follows, under ARIMA Model, there is no change for the preceding six months that is, constant flow also in Exponential smoothing and ANN model the data point is decreasing in nature.

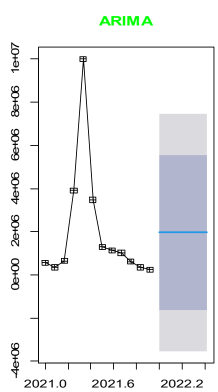


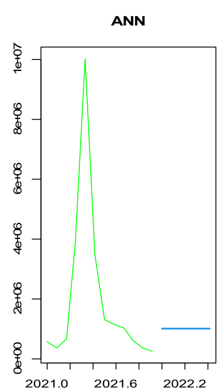


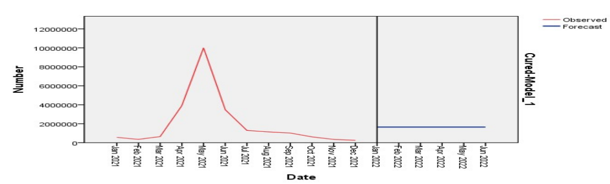


CURED CASES

The cumulative graph of cured cases in India for six months of forecasting is as follows,Under ARIMA model, it resembles as increased but does not reach the peak while in Exponential Smoothing model, the cured rate keeps increasing. In ANN, the flow of data point is gradually increasing.

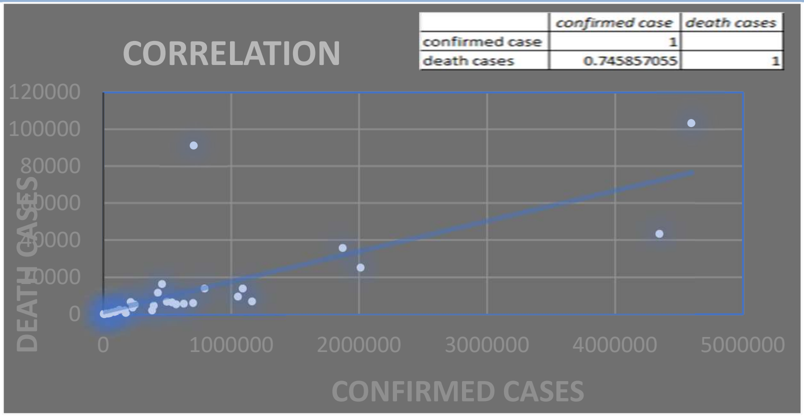






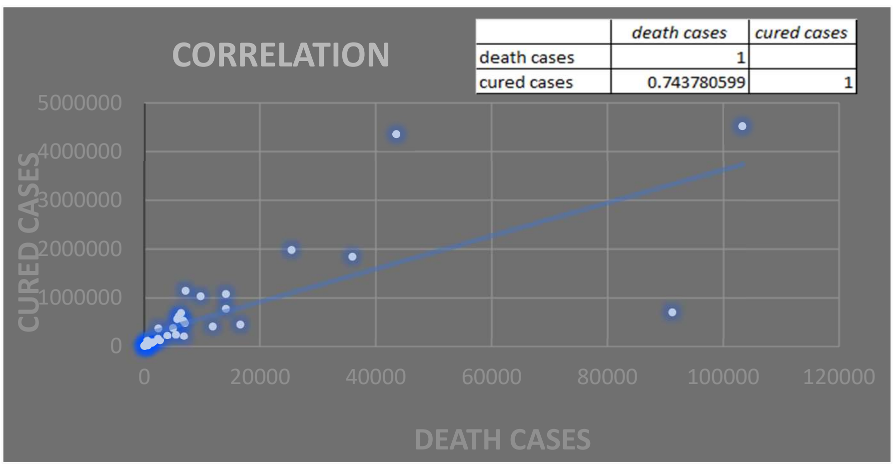
CORRELATION:

CONFIRMED CASES VS DEATH CASES



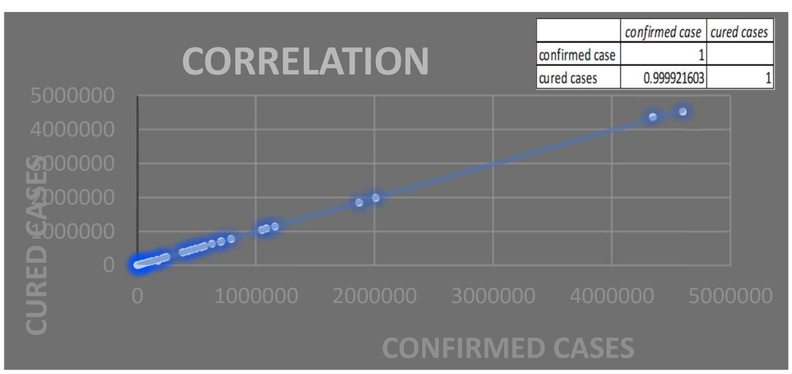
For cumulative data, the relationship between the confirmed cases and death cases are positively correlated ($r_{xy} = 0.74$), as the point lies closer to the straight line with positive gradient.

DEATH CASES VS CURED CASES



For cumulative data, the relationship between the cured cases and death cases are positively correlated ($r_{xy} = 0.74$), as the point lies closer to the straight line with positive gradient.

CURED CASES VS CONFIRMED CASES



For cumulative data, the relationship between the cured cases and confirmed cases are perfect positively correlated ($r_{xy} = 0.9$), as the point lies on the straight line with positive gradient.

ROOT MEAN SQUARE ERROR(RMSE):

RMSE is one of the standard ways to measure the error of a model in forecasting data. So, we calculated RMSE for each model (ARIMA, Exponential and ANN) and each variable (Confirmed, Death and Cured). The value of RMSE is given in the following tables.

ROOT MEAN SQUARE ERROR OF CONFIRMED CASES FOR THE MODELS ARIMA, EXPONENTIAL SMOOTHING AND ANN:

TABLE 3

RMSE for 36 states under Confirmed cases for the model ARIMA, Exponential smoothing and ANN

CONFIRMED CASES				
S.No	States	ARIMA	Exponential	ANN
1	Andaman and Nicobar	279.2832	313.654	31.02071
2	Andra Pradesh	160230.4	174508.7	123365.8
3	Arunachal Pradesh	3124.824	3434.627	186.6981
4	Assam	39735.61	44823.384	30466.21
5	Bihar	39735.61	85097.84	30464.85
6	Chandigarh	4021.622	5927.195	1343.362
7	Chhattisgarh	96196.65	121784.01	14551.37
8	Daman and Diu	910.759	1290.659	89.10774
9	Delhi	155043.9	151816.839	119037.5
10	Goa	17937.51	19462.115	13845.45
11	Gujarat	87896.45	93397.543	2636.639
12	Haryana	93839.47	91348.816	6686.297
13	Himachal Pradesh	24408.78	26545.291	18778.05
14	Jammu and Kashmir	30832.37	33400.992	21643.39
15	Jarkhand	42302.8	40914.665	1152.915
16	Karnataka	301298	327292.416	218929.3
17	Kerala	253790.8	276115.756	176602.5
18	Ladakh	1430.059	1469.253	205.9229
19	Lakshadweep	1444.878	1558.586	1113.857
20	Madya Pradesh	97040.34	92851.781	5628.968
21	Maharashtra	429124.4	479022.834	49767.54
22	Manipur	6865.27	7478.271	184.4697
23	Megalaya	5064.976	5535.75	4982.945
24	Mizoram	17026.46	17817.221	12725.24
25	Nagaland	2088.318	2257.309	1558.065
26	Odisha	87336.81	91573.275	59186.29
27	Puducherry	12355.95	13446.891	8110.334
28	Punjab	52698.31	60493.407	38706.43
29	Rajasthan	121678.9	119019.711	1617.147
30	Sikkim	1966.273	2156.612	1771.055
31	Tamil Nadu	249839.9	271777.016	189456.1
32	Telangana	45045.25	45116.864	2298.535
33	Tripura	4568.434	5056.93	308.1239
34	Uttar Pradesh	214688.8	210798.74	5821.969
35	Uttarakhand	47912.62	46914.198	35968.42
36	West Bengal	148826.7	161405.611	106374.9

TABLE 4

RMSE for 36 states under death cases for the models ARIMA, Exponential smoothing and ANN

DEATH CASES				
S.no	**States**	**ARIMA**	**Exponential**	**ANN**
1	Andaman and Nicobar	14.15392	14.13	10.29318
2	Andhra Pradesh	728.6691	823.986	181.8841
3	Arunachal Pradesh	16.88788	18.444	2.71979
4	Assam	575.6237	620.145	532.7783
5	Bihar	1983.742	2163.074	1294.8
6	Chandigarh	93.29891	105.262	85.5093
7	Chhattisgarh	4129.76	4313.396	3544.375
8	Daman and Diu	0.57735	0.594	0.572078
9	Delhi	2696.36	2632.201	2048.29
10	Goa	388.6064	415.074	315.5778
11	Gujarat	1049.242	1014.135	351.1341
12	Haryana	1049.242	1184.935	435.2099
13	Himachal Pradesh	288.83	314.793	187.6105
14	Jammu and Kashmir	1338.167	1314.161	1235.281
15	Jharkhand	786.5068	772.69	617.5433
16	Karnataka	3697.759	4026.117	2615.387
17	Kerala	1234.993	1289.917	2615.387
18	Ladakh	12.05773	12.82	9.504848
19	Lakshadweep	9.237604	8.96	5.645302
20	Madhya Pradesh	794.4222	822.203	644.254
21	Maharashtra	6560.665	8108.876	3652.482
22	Manipur	119.9266	131.41	8.696852
23	Meghalaya	126.7902	125.664	105.7359
24	Mizoram	27.75788	28.914	18.55779
25	Nagaland	71.36346	77.963	70.34189
26	Odissa	558.4598	617.061	67.96344
27	Pondicherry	217.9507	209.689	151.0323
28	Punjab	1476.701	1600.202	1138.121
29	Rajasthan	1241.479	1231.743	835.4501
30	Sikkim	28.41496	30.994	26.9991
31	Tamil Nadu	4412.451	4549.684	3614.969
32	Telangana	223.6462	54.446	108.8434
33	Tripura	41.46141	46.213	20.38574
34	Uttar Pradesh	2007.058	2448.748	881.0132
35	Uttarakhand	1129.836	1119.925	707.2022

36	West Bengal	1117.592	1213.481	217.3316

TABLE 5

RMSE for 36 states under cured cases for the models ARIMA, Exponential smoothing and ANN

CURED CASES				
S.No	**States**	**ARIMA**	**Exponential**	**ANN**
1	Andaman and Nicobar	184.3524	290.017	148.8135
2	Andhra Pradesh	155604.4	169594.408	118699.9
3	Arunachal Pradesh	2052.969	2840.169	200.0378
4	Assam	35958.73	40010.254	2767.583
5	Bihar	96159.48	95505.397	67606.99
6	Chandigarh	6200.316	6741.473	5016.51
7	Chhattisgarh	105632	112633.719	3551.542
8	Daman and Diu	1364.127	1339.87	948.3757
9	Delhi	147499.5	143390.325	3761.266
10	Goa	19248.6	20908.486	14961.33
11	Gujarat	106139.7	102925.589	71968.28
12	Haryana	102582.8	101838.21	72041.7
13	Himachal Pradesh	24396.83	26524.701	20175
14	Jammu and Kashmir	29046.73	31491.561	3944.227
15	Jharkhand	45519.19	44915.569	31533.56
16	Karnataka	304743.3	331342.981	216904.6
17	Kerala	272360.1	299452.867	259070.7
18	Ladakh	770.1872	1246.436	317.6916
19	Lakshadweep	1195.991	1427.397	900.7429
20	Madhya Pradesh	74780.47	92090.123	7926.676
21	Maharashtra	416549.8	464492.973	56314.61
22	Manipur	5878.721	6317.466	340.3061
23	Meghalaya	4198.48	4521.57	1229.017
24	Mizoram	7947.57	8300.989	6297.407
25	Nagaland	1945.476	1954.757	1376.079
26	Odisha	76735.34	87439.925	13022.46
27	Puducherry	11794.12	12842.597	8144.729
28	Punjab	58533.72	61246.933	44125.12
29	Rajasthan	137062.6	136996.158	91018.02
30	Sikkim	1852.401	2018.106	1615.558
31	Tamil Nadu	233492.9	234940.356	8819.117
32	Telangana	47345.7	51500.745	35883.76
33	Tripura	3191.272	4387.611	415.4121

34	Uttar Pradesh	220008.1	217359.599	162637.4
35	Uttarakhand	48953.71	48246.438	36824.04
36	West Bengal	149461.9	162178.588	116938.2

CONCLUSION

The analysis on covid-19 data is done. As we are intended to visualize the flow of the disease in India, covid-19 data was forecasted for the preceding months and the best fit for the models were estimated. The best fit for the time series model was found by comparing the Root Mean Square Error (RMSE) based on ARIMA, Exponential smoothing and Artificial Neural Networks(ANNs) with their respective cases confirmed, death and cured. While observing all the3 models with their corresponding RMSE, Neural network model is yielding the best fit among the other models. Reason of arriving at this result is because; the neural network model revises the input data till it reaches the desired accuracy rate. So the neural network model is the best model when compared with the other models ARIMA and Exponential smoothing.

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