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FORECASTING EPIDEMIC SPREAD OF COVID-19 IN INDIA USING ARIMA MODEL AND EFFECTIVENESS OF LOCKDOWN

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ABSTRACT. In the present situation, coronavirus which renamed as COVID 19 by World Health Organization is the most infectious illness spreading worldwide whose first case saw in China on December 31, 2019. India is the second most populated nation in the world; accordingly, it is a state of research to forecast the COVID-19 spread in India. Till May 03, 2020, 42,505 COVID-19 cases were confirmed in India including 1,391 deaths. COVID-19 infected patient data has extracted from the covidindia, kaggle and World Health Organization website which includes daily confirmed, recovered and death cases from February 15, 2020 to May, 03, 2020. In the current study, the data-driven estimation model ARIMA is utilized for determining the number of COVID-19 cases in India 76 days ahead from 03 May, 2020 using R statistical package. Predictions were done with average of 93.695% of accuracy for confirmed case models, 86.96% of accuracy for recovered case models, 87.94% for death case models and 90.91% for death rate respectively. The 76-day forecasting of COVID-19 contaminated patients could be ascend to 28,2529, recovered cases could be expanded up to 11,9046 and death cases could expanded up to 9675 at July, 18 2020 with Confidence Interval of 80% to 95%. This pioneering study mainly focus on the importance of nationwide three lockdown, self isolation and social distancing in control the disease transmissibility among Indian population through data driven ARIMA model analysis. The ARIMA model with Akaike's Information Criterion, Bayesian Information Criterion, and Ljung-Box Statistics test utilized for best model determination which can quickly help in estimating COVID-19 contaminated patients and help administration to make better decision to fight with this contagious disease.

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Key words and phrases. Auto-regressive integrated moving average (ARIMA) model;COVID-19; Epidemic; India; Forecast, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and Ljung-Box Statistics.

1. INTRODUCTION

In December 31, 2019, first instance of COVID-19 was seen in Wuhan city, China, with side effects particularly indistinguishable to normal influenza. Afterward, researcher in China and World health Organization (WHO) found that influenza is brought by a novel coronavirus (SARS-CoV-2) (Huang et al., 2020; L. Wang et al., 2020; Dhama et al., 2020). Clinical most basic side effects of this malady incorporate fever, dry hack, breathing trouble and tiredness and less regular features: respiratory manifestations, chest agony, and loss of discourse, loss of taste and smell just as cerebral pain. Most contaminated people will develop mild to moderate illness with good immune system and recover without hospitalization (Tomar et al., 2020, Perlman 2020) but those patients have moderate to severe illness can suffer from kidney disappointment, lung harm and even passing (Sohrabi et al., 2020; Xu et al., 2020; Statista, 2020). WHO renamed this profoundly infectious disease as Coronavirus Disease 2019 (COVID-19) in February 11, 2020 and WHO has announced it as an epidemic (WHO, 2020a).

Regardless of the huge number of cases worldwide (Yadav et al., 2020; Vellingiri at al.,2020; Tobias, 2020) and low death rate (Liu et al., 2020) contrasted with other epidemic this COVID-19 disease has high infectivity and transmissibility. The preventive measures for this ailment declared by WHO incorporates self isolation, social separating, washing hands repetitively, abstain from contacting the mouth, nose, and face (WHO, 2020a; Ceylan, 2020).The first instance of COVID-19 was seen in India on January 30, 2020 (PIB, 2020, WHO, 2020b). It spreads rapidly to the number of area of the nation. As on May 10, 2020 the total confirmed cases observed in India are 61000 with 472 recovered cases and 166 deaths (Covid-19.in, 2020).

As a preventive measure against the COVID-19 widespread in India, Indian government imposed nationwide three strict lockdowns March 25, 2020-April 14, 2020; April 15, 2020-03 May, 2020 and May 04, 2020- May 17, 2020 (Lockdown, 2020). It is observed that COVID 19 cases are still increasing, but if we compared with the other countries it is clearly visible that the rate of infection is lower and still in control in India, despite the second largest population among worldwide. By the time of this research article submission (May 11, 2020), India ranked fourteenth with respect to the number of confirmed infected people by this disease, total cases per million population was 47, total deaths per million population was 02 and total test conducted per million population was 1166 (Worldometers, 2020; WHO, 2020c). Till now, there's no particular treatment for this illness, and it spreads impressively around the world (Raoofi et al., 2020; Roosa et al., 2020).

The proposed ARIMA model can approximately foresee the number of new COVID-19 cases, total confirmed cases, total deaths, and death rate and growth rate from May 04,

2020 to July, 18, 2020 so; the administration and healthcare system can make preparations for providing medical services for future infected patients and basic amenities to general peoples. The ARIMA model with Akaike's Information Criterion, Bayesian Information Criterion, and Ljung-Box Statistics test (Mohamad, 2012; Clement, 2014) used for best model selection which can rapidly aid in forecasting COVID-19 infected patients and help administration to make better decision to fight with this contagious disease. For further reference, see [1-26].

2. Material and Methods

The daily total confirmed, total death, as well as recovered cases of COVID-19 infected patients from 15 Feb, 2020 (day 1) to 3 May, 2020 (day 79) in India were collected from the official website of the Ministry of Health (Covid-19.in, 2020, Covid-19 India, 2020; Covid-19 in India, 2020). Instead of observing whole data from January, we just considered observation from 15 February 2020 because before that hardly few cases are enlisted till mid of February. The data model development was done using ARIMA model and predict the trend of the daily total confirmed cases, total deaths, recovered cases from May 04, 2020 (day 80) to July18, 2020 (day 155). ARIMA stands for Autoregressive Integrated Moving Average model which followed approach by Box Jenkins (Box and Jenkins, 1976). ARIMA model are analyzed to forecast a future which is time dependent i.e. time series. ARIMA model was formed by combination of three models Autoregressive (AR), Integrated (I) and Moving Average (MA) models respectively (Chintalapudiet al., 2020; Tomar et al., 2020). The AR model depends only of past values and the general equation is given as:

$$X_t = f(X_{t-1}, X_{t-2}, X_{t-3}, \ldots),$$

$$X_t = \alpha_o + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \alpha_3 X_{t-3} + \ldots$$

where, $\alpha_i (i = 0, 1, 2,)$ are coefficients and X_t depends on X past values i.e. $X_{t-1}, X_{t-2}, X_{t-3}, \ldots$.

The MA model depends only on random error terms which are in general equation:

$$X_t = f(\varepsilon_t, \varepsilon_{t-1}, \varepsilon_{t-2}, \varepsilon_{t-3}, \ldots)$$

$$X_t = \alpha + \alpha_t + \theta_1 \varepsilon_{t-1} + \theta_1 \varepsilon_{t-2} + \theta_1 \varepsilon_{t-3} + \ldots,$$

where ε_t represents the error of the model as a combination of previous terms. For using ARIMA model, a series is said to be strictly stationary, when the mean, variance and covariance are steady over period of time. A series which isn't stationary can be made stationary to begin with after differencing. After differencing once, series is known as integrated of order one and denoted by I(1), generally I (d). ARIMA model specified by

three order parameters: p, d, and q where p stands for number of AR terms, d stands for non-seasonal differences are needed to achieve stationary (I) and q stands for number of lagged forecast errors in the prediction equation (MA).

To choose the appropriate parameter that can be fitted to the ARIMA model, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and Ljung-Box Statistics criteria were used (Akaike, 1974; Ljung and Box, 1978). As described by Akaike (1974), a good model exhibits the lowest AIC and it is defined by a simple equation as equation (2.1),

$$AIC = -2 * \ln(ML) + 2 * n \tag{2.1}$$

$$BIC = -2 * \ln(ML) + a(\ln)k \tag{2.2}$$

$$Q = n(n+2)\sum_{t=1}^{k} \frac{rt^2}{n-t}, \tag{2.3}$$

where, ML is the value of the maximum likelihood and n is the number of parameters fit. As described by Scott I. Vrieze (2012), a good model exhibits the lowest among a limited set of models and it is defined by a simple equation as equation (2.2). Here, 'a' be the number of parameters in the model, 'k' be the sample size and ML be the value of the maximum likelihood. The Ljung–Box statistic test applied to residuals after an estimate model has been fit to the data. If the autocorrelations of the residuals are very small, at that point the model doesn't show 'significant lack of fit'. LjungâĂŞBox test developed two scientists such as Greta Marianne Ljung, George Edward Pelham Box and name given as Ljung–Box test. It tests the overall randomness of time series data set on different lags. This test mainly applied on economic data and time series data sets.(Mohamad, 2012; Clement, 2014). The statistics of Ljung–Box test is defined as equation (2.3).

Where, n be the number of observations, t is the length of coefficients to test autocorrelation, t be the estimated autocorrelation between observations separated by t time periods. Microsoft Excel was used to build the database of day by day COVID-19 disease information, and R Language was utilized to build the ARIMA model.

3. Results And Discussion

On May 03, 2020, India reported 2,806 confirmed cases of COVID-19 infection (total of 42,505) with 68 Coronavirus-related deaths; the overall death toll has reached 1,391. India announced its first confirmed COVID-19 infection case in January 30, 2020 and the first death in the country were officially reported on March 12, 2020. The total cases of COVID-19 infection have rapidly increased in India, with a peak from March 29 to till now. After this period, the total number of confirmed new cases, new deaths, as

well as the growth rate increased even the strict quarantine and control imposed by the government (Fig. 1). Patient data divide into three groups, confirmed, recovered and deaths cases, daily confirmed cases, death rate and recovered rate derived from these three groups. For this study we collected total 79 days data from 15 February, 2020 to 3 May, 2020 because before 15 February 2020 no epidemic was declared in India. Fig 1 shows that confirmed recovered deaths and daily confirmed cases increasing exponentially which means that data is not stationary. To make the time data stationary we used the differencing in the ARIMA model, two differencing is used to make the data stationary after that we choose the appropriate ARIMA model on the base of AIC, BIC, p-value for Ljung–Box test (Fig. 2) and decide the value p (AR) and q (MA) value. Autocorrelation Function (ACF) examines the correlation between the current and the previous time spot observations values. Partial Autocorrelation Function (PACF) presents the correlation between observations at two time spots and its given intermediate time spots.

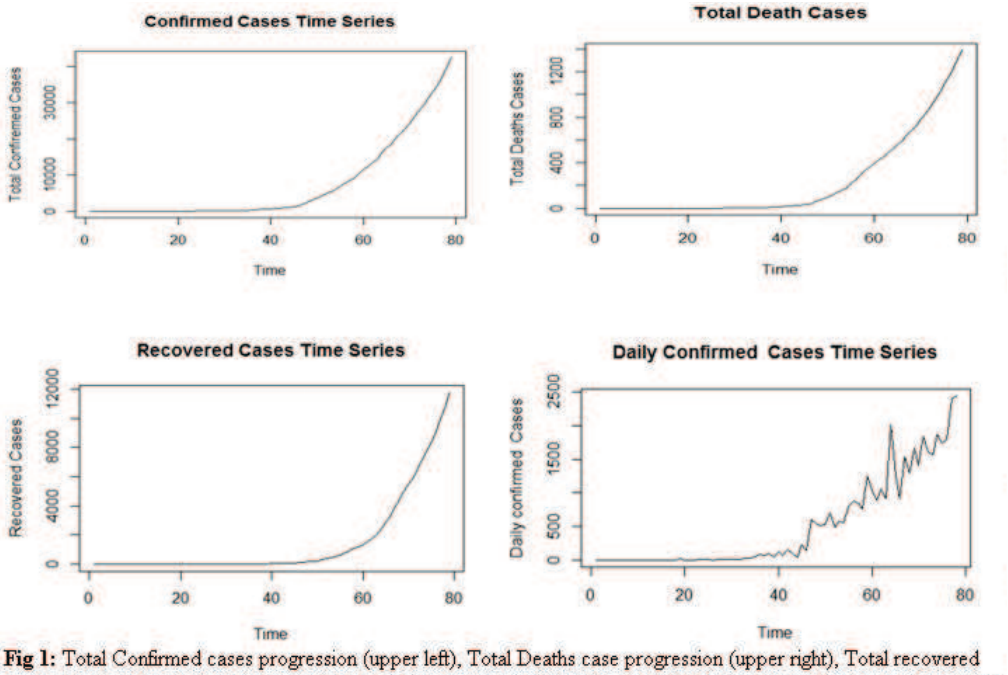

Fig 1: Total Confirmed cases progression (upper left), Total Deaths case progression (upper right), Total recovered Cases Progression (Lower Left) and Daily confirmed cases (lower right)of COVID-19 in India (February 15, 2020 to May 03, 2020)

Fig. 3 depicts the PACF value taking after two differencing for total confirmed, total deaths, total recovered and daily confirmed cases. PACF decide the value of q, which is the moving average (MA), ACF decide the value of p, which mean Autoregressive (AR) value in ARIMA Model. Differencing is denoted by d which is used to make the time series data stationary and removal of seasonal and other factor from the data. Table 1 shows the ARIMA model with diverse values of p, d, q and AIC for different cases.

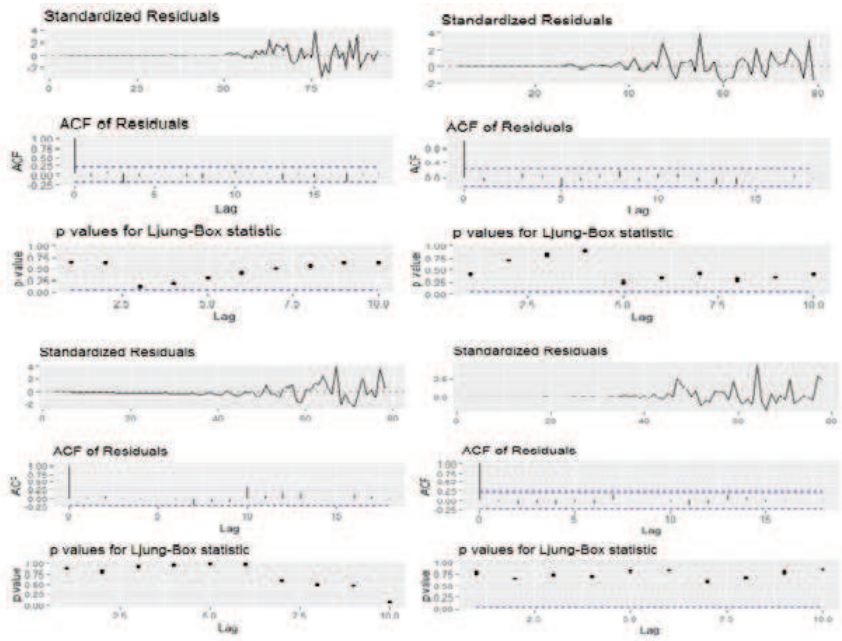

Fig 2: Standardized Residual, ACF and p value for Ljung-Box for Total Confirmed cases (upper left) , Total Deaths case (upper right), Total recovered Cases (Lower Left) and Daily confirmed cases (Lower Right) of COVID-19 in India (February 15, 2020 to May 03, 2020)

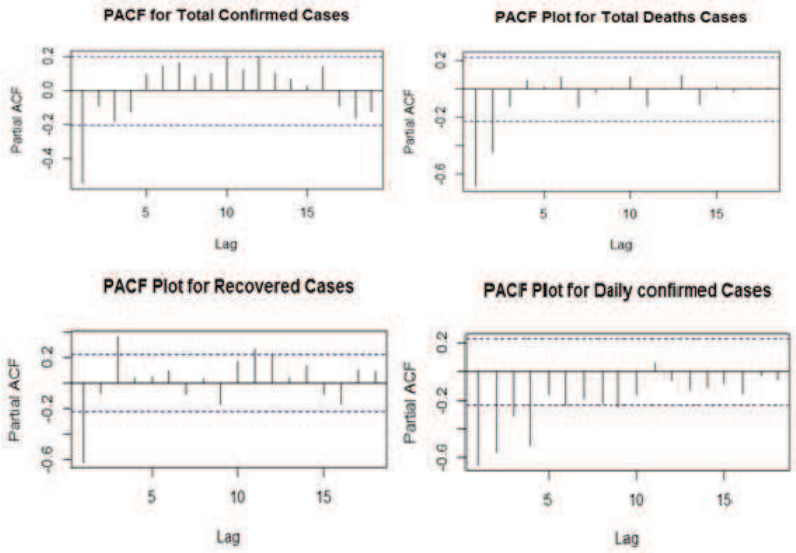

Fig 3 : Total Confirmed cases PACF (upper left) , Total Deaths case PACF (upper right), Total recovered Cases PACF (Lower Left) and Daily confirmed cases PACF (Lower Right) of COVID-19 in India (February 15, 2020 to May 03, 2020)

Table 2 shows the best ARIMA model with diverse values of p, d, q, AIC value and p–value of Ljung–Box test for confirmed, recovered, deaths, daily confirmed cases and

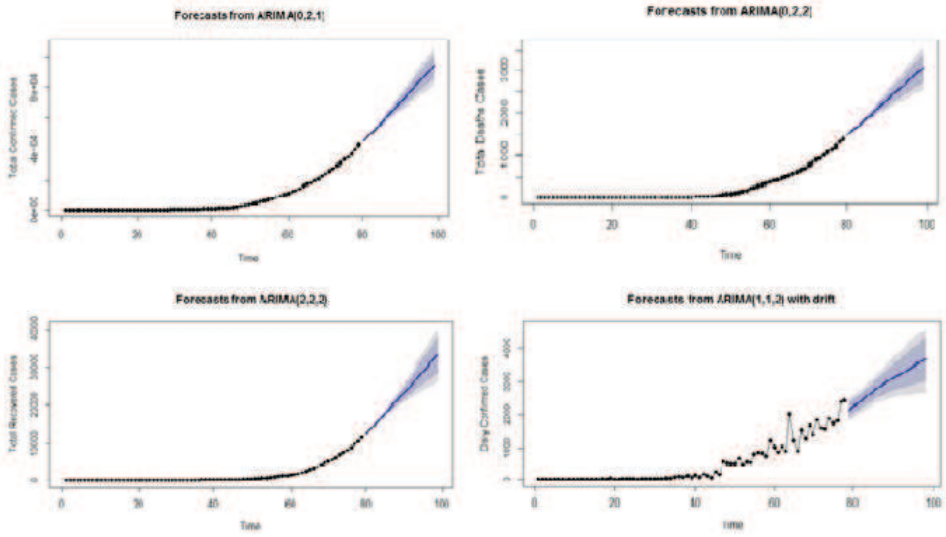

Fig 4: Prediction and Confidence Intervals (CI) for Total Confirmed cases (upper left) , Total Deaths case (upper right), Total recovered Cases (Lower Left) and Daily confirmed cases (Lower Right) of COVID-19 infection in India (May 04, 2020 to May 18, 2020) (Black line shows actual data, Blue line shows 15-day forecast, Gray zone shows 80% of CI and White zone shows 95% of CI).

Table 1: ARIMA model with diverse p, d, q and AIC values

ARIMA Model With Different p, d, q value	AIC Value for Total Confirmed Cases	AIC Value for Total Recovered Cases	AIC Value for Total Deaths Cases	ARIMA Model With Different p, d, q value	AIC Value for Daily confirmed cases	AIC Value for Deaths rate
ARIMA(2,2,2)	**inf**	860.63	513.397	ARIMA(2,1,2) with drift	1027.13	28.20
ARIMA(0,2,0)	1060	896.94	566.003	ARIMA(0,1,0) with drift	1058.14	22.52
ARIMA(1,2,0)	1046.39	865.55	527.100	ARIMA(1,1,0) with drift	1041.17	24.66
ARIMA(0,2,1)	1045.772	878.71	536.961	ARIMA(0,1,1) with drift	1033.067	24.64
ARIMA(1,2,2)	inf	862.22	512.024	ARIMA(0,1,0)	1057.519	22.26
ARIMA(0,2,2)	1045.856	886.21	510.369	ARIMA(1,1,2) with drift	1024.941	Inf
ARIMA(0,2,3)	1100.45	898.13	511.912	ARIMA(0,1,2) with drift	**1034.02**	**Inf**

*inf stands for infinity

death rate. This test is the statistical test find the autocorrelation for time series data set. As the p–value for the Ljung–Box test is more than 0.05, the hypothesis would not be rejected at the 95.0% confidence level and if the p-valueis less than 0.05 reject the

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hypothesis. Here, the p–value >0.5 therefore, the chosen models are likely satisfactory for the information. From Table 3, India could easily exhibit an upward trend for the total number confirmed, recovered, death cases, daily confirmed cases and death rate by using ARIMA Model with minimum AIC Value from May 04, 2020 to July 18, 2020 (76 days). It shows that death rate is constant 3.27% but upper and lower bound change and broader between 1.17 and 5.36. Table 3 also depicts the forecast for 76 days in difference of one week up to July 18, 2020 with the 95% confidence interval for different variables. The 15-days COVID-19 forecasting graphs of total confirmed, total deaths, total recovered and daily confirmed cases from May 04, 2020 to May 18, 2020 (Fig. 4) The probability of total confirmed, total death, total recovered and daily confirmed cases in India for next seventy six days based on available data were evaluated. It is discernible from Fig. 5 and Table 3, the 76- day forecasting of total confirmed cases might rise in between the span of 44838-282529, death cases may increased in between the span of 1480-9675 and recovered cases could increased in between the span of 12559-119046 and daily confirmed cases could increased in between the span of 2130-5922 with CI of 80 to 95

Table 4 presents the comparison of various ARIMA model results and accuracy parameters. This table predicts the error for different ARIMA models such as Confirmed cases ARIMA(2,2,3), Confirmed cases ARIMA(2,2,2), Deaths cases ARIMA(0,2,2), Deaths cases ARIMA(0,2,3), Recovered cases ARIMA(0,2,2), Recovered cases ARIMA(0,2,3),

Table 3: Forecasting of total confirmed, total deaths, total recovered, daily confirmed and death rate in India for the next 76 days using ARIMA models

Date (mm/dd/yyyy)	Total confirmed cases ARIMA (2,2,2)	Total Death cases ARIMA(0,2,2)	Total Recovered Cases ARIMA (0,2,2)	Daily Confirmed Cases ARIMA (1,1,2)	Death Rate (%)
05/04/2020	44838 (44325-45350)	1480(1467-1492)	12559(12188-12930)	2130(1785-2475)	3.27(2.72-3.81)
05/11/2020	66509 (62809-70209)	2064(1930- 2197)	18836 (16942-20730)	2815(2366-3265)	3.27(1.74 4.79)
05/18/2020	90238 (79113-101363)	2647(2302- 2993)	25113(20714- 29512)	3355 (2607- 4103)	3.27(1.17-5.36)
05/25/2020	113013(99941-126085)	3832(3322-4341)	41443(35211-47674)	3866(2457-5274)	3.27(1.19-5.50)
06/01/2020	134988(112971-157006)	4589(3751-5427)	51502(40885-62120)	4137(2478-5796)	3.27(.79-5.90)
06/08/2020	156963(124569-189356)	5347(4130-6563)	61562(45833-77291)	4409(2532-6285)	3.27(0.44-6.25)
06/15/2020	178937(134913-222960)	6104(4464-7744)	71622(50148-93095)	4680(2609-6751)	3.27(0.13-6.56)
06/22/2020	200911(144124-257697)	6861(4758-8965)	81681(53895-109468)	4913(2689-7137)	3.27(-0.14-6.85)
06/29/2020	222885(152297-293473)	7619(5015-10222)	91741(57121-126362)	5185(2794-7575)	3.27(-0.41-7.11)
07/06/2020	244859(159503-330214)	8376(5238-11514)	101801(59862-143739)	5456(2910-8003)	3.27(-0.66-7.35)
07/13/2020	266833(165803-367863)	9134(5428-12839)	111860(62150-161570)	5766(3053-8480)	3.27(-0.89-7.59)
07/18/2020	282529(169776-395281)	9675(5546-13803)	119046(63521-174571)	5922(3128-8715)	3.35(-1.015-7.71)

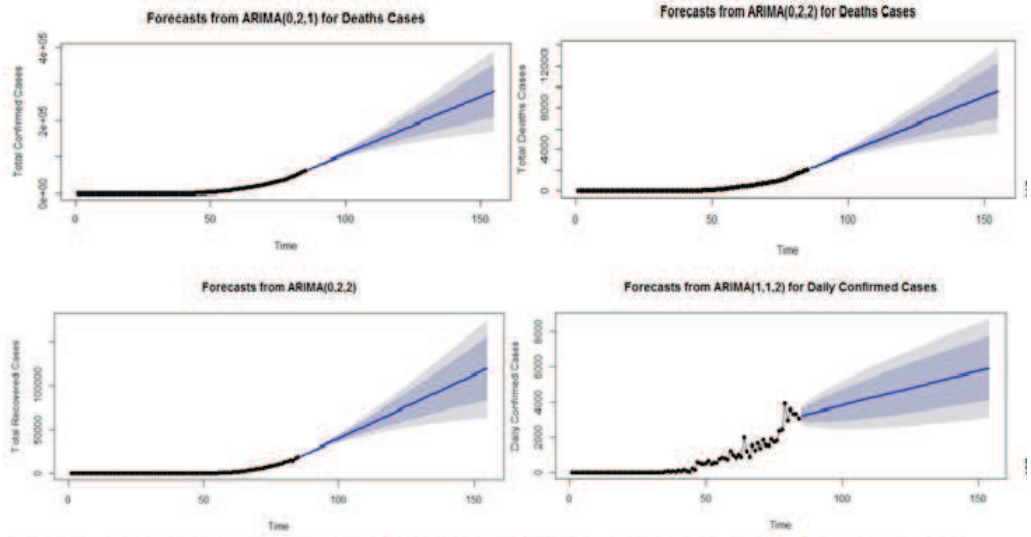

Fig 5: Prediction and Confidence Intervals (CI) for Total Confirmed cases (upper left) , Total Deaths case (upper right), Total recovered Cases (Lower Left) and Daily confirmed cases (Lower Right) of COVID-19 infection in India (May 10, 2020 to July 18, 2020) (Black line shows actual data, Blue line shows 76-day forecast, Gray zone shows 80% of CI and White zone shows 95% of CI).

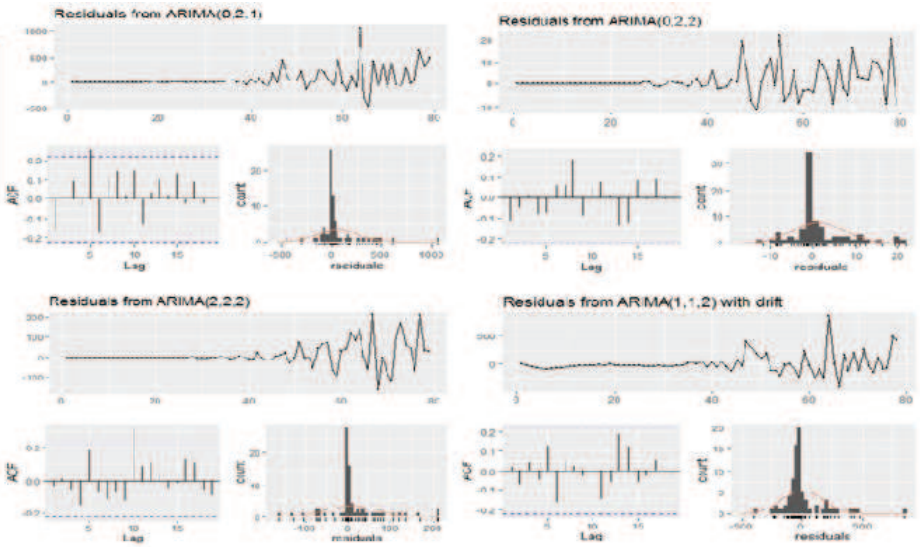

Fig. 6: ARIMA Model Residual for Total Confirmed cases (upper left) , Total Deaths case (upper right), Total recovered Cases (Lower Left) and Daily confirmed cases (Lower Right) of COVID-19 in India (May 03, 2020 to July 18, 2020)

Daily Confirmed cases ARIMA(1,1,2), Death Rate ARIMA(0,1,0). Based on the ARIMA model accuracy evolution of COVID-19 Indian epidemic data on mentioned time period, weconsidered various parameters: S.E. stands for Standard Error, ar1, ar2, ma1, ma2, ma3 are the coefficients of ARIMA Model and ME stands for Margin of error; RMSE stands for Root mean square error of fitted model; MAE stands for Mean absolute error; MPE stands for Mean posterior estimate; MAPE stands for Median absolute prediction error; MASE stands for Mean absolute scaled error and ACF stands for Aberrant crypt foci.The forecast accuracy measurement is computed by general equation (3.1);

$$Accuracy = 100 - MAPE \tag{3.1}$$

The models of ARIMA(0,2,1) confirmed, ARIMA(0,2,2) confirmed, ARIMA(0,2,2) deaths, ARIMA(0,2,3) deaths, ARIMA(0,2,2) recovered, ARIMA(0,2,3) recovered, and ARIMA(0,1,0)death rate are validated with an accuracy of 93.76%,93.63%, 87.98%, 87.9%, 86.91%, 87.01% and 90.91% respectively. The model validation was assessed by prediction errors and Fig. 6 presents ARIMA Model Residual for Total Confirmed cases, total deaths case, total recovered Cases and daily confirmed cases of COVID-19 infection in India from May 04, 2020 to July 18, 2020.

4. Conclusion

Indian government imposed nationwide strict lockdowns in three phases: Phase 1: March 25, 2020-April 14, 2020 (21 days); Phase 2: April 15, 2020-03 May, 2020 (19

Table 4: Comparison of various ARIMA models

Model	ar1	ar2	ma1	ma2	ma3	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Confirmed ARIMA(0,2,1)	-	-	-1.095	-	0.53	69.3	275.37	130.25	2.499	6.237	0.233	-0.124
S.e.	1.2268	0.7311	1.247	2.0484	1.1712	-	-	-	-	-	-	-
Confirmed ARIMA(0,2,2)	-	-	-1.66	0.926	-	51.24	251.36	127.28	2.28	6.37	0.228	-0.034
S.e.	0.1323	0.1403	0.0681	0.0679	-	-	-	-	-	-	-	-
Deaths ARIMA (0,2,2)	-	-	-0.8333	0.6838	-	1.27	6.24	3.66	2.37	12.02	0.21	-0.118
S.e.	-	-	0.0824	0.0809	-	-	-	-	-	-	-	-
Deaths ARIMA (0,2,3)	-	-	0.9184	0.7709	-0.105	1.42	6.21	3.69	2.76	12.1	0.206	-0.069
S.e.	-	-	0.1133	0.1304	0.1253	-	-	-	-	-	-	-
Recovered cases ARIMA(0,2,2)	-	-	-1.1444	0.4809	-	35.88	184.29	74.06	9.33	13.093	0.421	-309
S.e	-	-	0.1007	0.1094	-	-	-	-	-	-	-	-
Recovered cases ARIMA(0,2,3)	-	-	-1.1443	0.4405	0.034	34.82	184.17	3.7	9.24	12.99	0.419	-0.05
S.e	-	-	0.1144	0.1421	0.1023	-	-	-	-	-	-	-
Daily Confirmed cases ARIMA(1,1,2)	0.9423		-1.8484	0.9259	-	7.78	170.1	101.13	-Inf	Inf	0.8548	0.0191
S.e	0.049		0.0904	0.0997	-	-	-	-	-	-	-	-
Death Rate ARIMA(0,1,0)	-	-	-	-	-	0.042	0.2741	0.1319	2.7177	9.0992	0.9871	-0.019

days) and Phase 3: May 04, 2020- May 17, 2020, as a preventive measure against the COVID-19 pandemic in India. Indian government take huge step of social isolation, national lockdown, shut down malls, school and colleges very early into the spread of the COVID-19 infection in the country, with around 657 cases and 12 deaths (25 March, 2020).It is observed that COVID 19 cases are still increasing, but if we compared with the other countries it is clearly visible that the percentage increases of COVID 19 cases are still in control in India, as the population of India is amongst the largest of the world nearly 1.3 billion and the number of confirmed cases reported till May 10, 2020 are 67,277. The daily average growth rate of confirmed cases during 15 February, 2020 to 25 March, 2020 (40 days) is 10.169%. Rather than observing entire data from January, we only considered observation from 01March 2020 because before that only few cases i.e. three confirmed cases are reported. The daily average growth rate of confirmed cases during 01 March, 2020 to 25 March, 2020 (25 days) was 16.99%. As Indian government imposed three national lockdowns, in first phase i.e. 26 March to 14 April, 2020 daily growth rate of confirmed cases was 13.136%, in second phase of lockdown i.e. 15 April to 03 May, 2020 daily growth rate of confirmed cases was 7.01% and in third phase of lockdown from 04 May to 10 May 2020 (till submission of

article) confirmed case growth rate is 6.29 %. This clearly shows that in spite of India's shows a steady rise in new confirmed cases but growth rate is still decreasing due to strict lockdown from 13.136% to 6.29%. The study shows that predicted growth rate from May 18, 2020 to July 18, 2020 seems declined to 1.11% and in end of October 2020 growth rate will becomes below 0.5%. The recovery rate of COVID-19 infected patients from March 01 to March 25, 2020 was 12.38%, but it shows improvement in first phase of lockdown, it becomes 13.39% as well as recovery rate shows upward trends in second lockdown 21.1% and in third phase of lockdown till May 10, 2020 it becomes 28.65%. The conclusion of present study suggests that we have to be prepared to live with COVID-19 with all the safety measures like social isolation, washing hands frequently, wear mask at face after the lockdown period until the end of 2020.

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