"COVID-19" Forecast Using Time Series Methods

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Abstract: The coronavirus "COVID-19" pandemic spreading over the world. This paper presents three time series models, exponential smoothing, Prophet additive forecast and Holts forecast method on understanding predictive patterns from published data on the number of "COVID-19" infected with coronavirus in India. This paper objective to introduce a different effective time series method to predict "COVID-19" forecast. The paper presented "COVID-19" confirmed cases in India till 30 June 2020. The data set used was from the Ministry of Health & Family Welfare and COVID 19india published through kaggle. The simple exponential smoothing model was applied using the Tableau tool. Prophet additive forecast method applied using R language and Holt method used in SPSS tool.

Index Terms: Coronavirus, "COVID-19", Day Level Forecasting, time series algorithms, Exponential Smoothing.

1. INTRODUCTION

Prediction or forecasting are the terms used to state about what will happen in the future. Different methods are employed in making this statement "as True as Possible" to reality. These methods are derived out of the prior art, knowledge, experiences and methods. These methods are driven by knowledge and/or intuition. Researchers across the globe have developed a number of such models based on various mathematical and statistical theories. "All models are wrong but few are useful" is a quite common statement saying about these models. Yet, there are instances when individuals, communities, nations and governments take solace in such predictions. Sometimes these predictions enable and empower the user with capacities to control the situation. This is very true considering the current "COVID-19 situation". Coronavirus infection ("COVID-19") is caused by a newly identified coronavirus. Those who fall sick with "COVID-19" will experience with mild to severe symptoms and can recover from special treatment. Other individuals who come in contact with an infected surface and then touches /her own face, especially nose, eyes and mouth have a very high probability of getting infected. A Public Health Emergency of International Concern was announced by the "World Health Organization" (WHO) on 30 January 2020 and an outbreak by the virus was named as "COVID-19" on 11 February 2020.[1] In response to this pandemic, there are various collaborative efforts taking place to limit the scope and spread of this disease outbreak. From limited economic activities to call for stay home, from making work from home a norm to providing shelter to homeless during these hard times, Governments are making all efforts to manage the pandemic. On the other hand there are a number of experts who are engaged in creating solutions in the form of vaccines, technology support and building models of prediction to help the local government. It is important for experts to respond with estimation of possible impact of the epidemic. The number of confirmed cases, recovered cases and the patter with which the disease spread and other related information will help the stakeholders to take informed decisions. [2]

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Authors of the present paper attempted to use the secondary data of "COVID-19", to predict the cases. The paper is outline as follows. Section 2 covers the literature review of the possible methods that are used for prediction. Section 3 talks about the methodology the paper has employed. Section 4 lists the findings and results and lastly Section 5 provided concluding remarks of the paper.

2 LITERATURE REVIEW

Pandemic spread has recurred very regularly on this planet. Records of such information as old as from the 3000 Century BC [3] are available in the literature. During times of health emergencies, it becomes imperative to study the spread, the preventive measures, and the future actions. Every time during such pandemics, researchers and experts have come forward to provide various solutions to tackle such a situation, "COVID-19" pandemic is no exception for the same. Expert studies during the pandemic varies and is multidisciplinary. From the cause to mitigate effects and prevent/protect the future, researchers across the globe have put in their efforts to guide the stakeholders. The current situation has added one more dimension to this and that is 'the world is a connected place now' and hence the dimension is Data. The internet and its connectivity has enabled individuals with access to huge amounts of data. The data generated, till date records the number of people infected, recovered and died. This nature and sequence of such collected data helps in building robust models to predict the spread of the pandemic in future.[4] Statistical methods like time series analysis and mathematical models with least error and better fit have been reported in the literature. Benzekry et al used different mathematical methods to describe and predict tumor growth despite its internal complexities. Authors of this paper used a three stage strategy of measurement of error, goodness of fit and the model's ability to forecast future tumor growth. They used a number of models yet the prediction rate remained less than 70%. [5] A tripod strategy is used where groups created models for specific management of the situation working independently. In the second stage modeling of the models takes place through discussions and comparisons. The groups worked independently to refine from the insights of stage two. In the last stage an overall projection for each management strategy evolves to help and mitigate the risks. [6] Lixiang et al predicted important factors affecting the spread of "COVID-19", such as the number of basic regenerations by Gaussian distribution with the standard deviation of 1.5. Model shows 11

days from the initial incubation of infection but not all 11 days of incubation for infected symptoms but simulation indicate average numbers of infection to 8 days. [7] Roda et al have used AIC (Akaike Information Criterion) for model selection to show comparison between SEIR(Susceptible Exposed Infectious Recovered) and SIR(Susceptible Infected Recovered) models. Their results of SIR modeling were better than SEIR. [8] Pourhomayoun et al have used Artificial Intelligence (AI) based Machine Learning (ML) for forecasting and results demonstrating 93% overall accuracy in predicting the mortality rate due to "COVID-19". They used machine learning algorithm to predict the mortality rate in infected people with "COVID-19". [9] Perc et al have predicted the "COVID-19" spread for four countries, Iran, USA, Germany and Slovenia for a period of two weeks. Keeping the alarming numbers in mind authors have recommended maintaining an average growth rate less than 5 % should be an important target. [10] An interactive dashboard was released by Dong E, Du H, and Gardner L in February 2020 for "COVID-19" predictions. The dashboard was aligned to the data set by Chinese and WHO reports and is available as a shared repository. [11], [12] . However, the current paper presents predictions of "COVID-19" confirmed cases. An attempt of using different forecasting methods like simple exponential smoothing with additive trend was planned, Prophet additive forecast and Holts methods. The details of the methods used are provided in Section 3.

3 METHODOLOGY

Due to the development of technologies like internet and information communication technologies, accessing "COVID-19" data has become simpler. The data is suitable for time series analysis. An exponential function assigned with decreasing weights over time can be applied to time series data. The present paper makes use of exponential smoothing from time series family [13], [14]. This time series method shown good forecast accuracy over various other forecasting methods [15], [16]. It is exclusively suitable for short period of dataset. Exponential smoothing method will capture a different trends and seasonal forecast patterns like additive, multiplicative or both pattern. In exponential smoothing, latest observations are given high weight than previous observations. This models consider the changing trend, seasonality of the data and calculate future forecast value. Exponential smoothing method create future value considering weighted averages of earlier values. This forecast method is considered as exponential because the value at each date is influenced by previous actual value which is exponentially decreasing and latest values assigned as greater weight. As the more data points in the time series will result into accurate forecast results. In Exponential smoothing, weight assigned to lag values is exponentially decline. Latest period assigned the higher weight than the previous time period. It uses a linear combination of past values. There are three types of smoothing methods based on the trend, seasonality and number of smoothing factors. Basic, Double, Triple exponential smoothing which has smoothing factor alpha, beta, gamma with variation in the equation with respect to smoothing factor. The present paper adapted the basic exponential smoothing and used the model as presented in Equ. 1.

$$S_t = \propto y_{t-1} + (1-\propto)\, S_{t-1} \quad (1)$$

Wherein

A → 0 < α ≤ 1

$\propto$ is smoothing constant. Its value in the rage of 0 to 1.

When $\propto \rightarrow$ zero, smoothing happens very slowly.

When $\propto$ = 0 then current smoothed point set to the previous smoothed value.

When $\propto$ = 1 then current smoothed point set to the current point.

t = Time period, t > 0

S_{t-1} = Forecast of previous date

y_{t-1} = Actual cases of previous date

S_t = Forecast for current date

Additive component is present and being added to the other components to create the complete forecast value. [17]. The forecast error (e_t) is difference between current value and forecast of current period predicted at last period. (Eq.3). The forecast error calculation provides a quantitative measure of the forecast quality.

$$e_t = y_t - S_{t-1} \quad (2)$$

$$\text{MAE} = \frac{1}{n}\sum |e_t| \quad (3)$$

$$MASE = \frac{MAE}{MAE_n} \quad (4)$$

Wherein [18]

S_{t-1} = Forecast predicted at previous day

y_t = Actual confirmed cases

e_t = Forecast error

n = Number of period

MAE = Mean Absolute error using exponential smoothing

MAE_n= Mean absolute error of Naive forecast

MASE (Mean Absolute Scaled Error) measure accuracy of forecasts with help of calculated MAE. It is the division of MAE of the forecast and MAE of the naive forecast value.

3.1 Dataset

Statistical data published by Ministry of Health & Family Welfare and covid19india, is taken from kaggle [15]. Data is published in csv file format and it has columns for confirmed cases, recovered cases and death cases for each state and date started from 30-Jan-20, it was the first day of the publication in India. This dataset has 106 days statistics for confirmed, recovered and death cases and data is published daily hence by the time paper publishes the days in the dataset will be increased.

3.2 Tableau

Tableau is a licensed analytics tool which help anyone to see and understand data with simple steps. Tableau provide features to create dashboards, graphs, tables which provide details insight into data and create meaningful results for business. The exponential model can be built by using the reference mathematical models as mentioned in Equ. 1 to Equ. 4. The present models were built by using additive component forecasts in exponential smoothing. Tableau automatically choose the best model out of eight which provide high quality forecast [19].

The results obtained under two sections i.e., "COVID-19" prediction Model for India and the model accuracy. These are presented in the section 4.

3.3 Prophet R-Language Library Prophet

Prophet analytics R language library used to predict the forecast. Underlying implementation of model is in the library. [23] Prophet is mostly used to shift the trend and handle outliner in time series. Prophet is used in many Facebook applications to predict future values. It is used to find yearly, monthly, weekly, daily seasonality and non-linear trend fits with additive method.[24] Accuracy of model represented by R-squared and p-Value value.

4 "COVID-19" FORECAST

Using different tools and time series methods we generated the prediction as per the following objectives

1. Estimate the "COVID-19" Confirmed cases for India and using different model
2. Describe the model accuracy

4.1 Estimate the "COVID-19" Confirmed Cases for India and using Simple Exponential Smoothing

Forecast is generated till 30-Jun-20 days using Tableau time series method. Tableau Desktop 2020.2 version is used to generate forecast and graphs.

TABLE. 1 *NUMBER OF CONFIRMED CASES AND PREDICTED FORECAST TILL 30-JUN-20*

Day of Date	Lower Prediction Interval for Confirmed	Upper Prediction Interval for Confirmed	Confirmed
30-Jun-20	350933	419969	385451
29-Jun-20	345478	411698	378588
28-Jun-20	340004	403447	371726
27-Jun-20	334509	395216	364863
26-Jun-20	328995	387006	358000
25-Jun-20	323459	378816	351137
24-Jun-20	317903	370647	344275
23-Jun-20	312325	362499	337412
22-Jun-20	306725	354373	330549
21-Jun-20	301104	346269	323686
20-Jun-20	295460	338187	316824
19-Jun-20	289793	330129	309961
18-Jun-20	284103	322093	303098
17-Jun-20	278389	314082	296235
16-Jun-20	272650	306095	289373
15-Jun-20	266887	298133	282510
14-Jun-20	261098	290196	275647
13-Jun-20	255283	282286	268784
12-Jun-20	249441	274402	261922
11-Jun-20	243572	266546	255059
10-Jun-20	237674	258718	248196
09-Jun-20	231746	250920	241333
08-Jun-20	225788	243153	234471
07-Jun-20	219799	235417	227608
06-Jun-20	213776	227714	220745
05-Jun-20	207719	220045	213882
04-Jun-20	201626	212413	207019
03-Jun-20	195493	204820	200157
02-Jun-20	189319	197268	193294
01-Jun-20	183100	189762	186431
31-May-20	176831	182306	179568
30-May-20	170504	174908	172706
29-May-20	164107	167579	165843
28-May-20	157625	160335	158980
27-May-20	151033	153202	152117

Table 1 shows "COVID-19" Forecast from 27-May-20 till 30-Jun-20 for India, it shows upper and lower range predicted by model. Considering the capacity to tackle such a level of pandemic the Government of India was into Lockdown of the country and measures like stay home, maintain social distancing etc. The results are imperative and hence India's "COVID-19" spread to reach 200000 might need more than 135 days. Table 2 tabulates the number of days required to reach milestones. [12]

TABLE. 2 *"COVID-19" CONFIRMED CASES IN FIVE COUNTRIES*

Name of country |	Number of Days to reach confirmed "COVID-19" cases			
Number →	10000	50000	100000	150000
USA	58	63	66	114
Spain	46	55	61	76
India	75	98	118	126
South Korea	72	Not Reached yet	Not Reached yet	Not Reached yet
Italy	40	51	60	77

Fig. 1 shows a forecast for 35 days on the number of "COVID-19" confirmed cases. No data point is ignored for previous period data while forecast prediction. The nature of virus spread brings the estimates to the higher side. Fig. 2. Shows different country confirmed cases to support table 2.

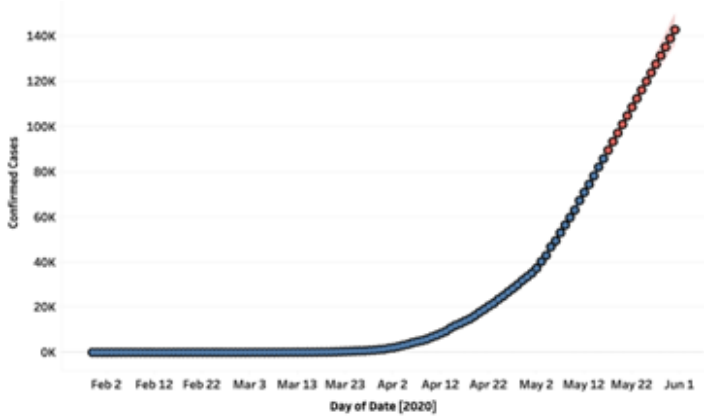

Figure 1. *Predicted forecast using Exponential smoothing method from 27-May-20 till 30-Jun-20*

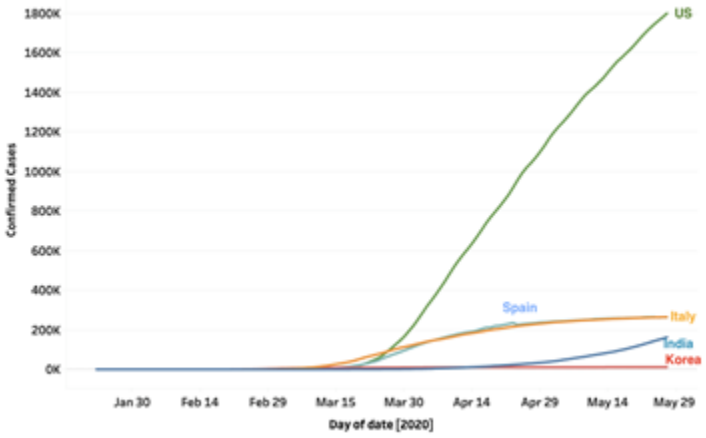

***Figure 2**. "COVID-19" confirmed cases in five countries.*

Model Accuracy

Quality metrics measure how good the model is to match with the future Data Generation process. Tableau select the best model out of eight to generate forecast with minimum error [20]. Forecast confidence interval used was 95%. Exponential smoothing method use weighted average of previous period to calculate forecast figure. Exponential Smoothing method calculate the smoothed value from a weighted average of the previous value. [21]. The method is exponential because the value of each level is compared with previous actual value with exponentially decreasing grade and most recent values allocate with greater weight. The model accuracy is evaluated based on various levels of errors the model has generated. For example, value of MASE. This has properties which are favorable to the time series data that was used to predict "COVID-19" confirmed cases. Therefore, the present paper monitored the value of MASE for the following four predict done on Table 3 describes the value of this error captured at four different instances, on the Tableau model.

***TABLE. 3** MASE MEASURED AT DIFFERENT INSTANCES OF MODEL*

Model Milestone Dates	Mean Absolute Scaled Error(MASE)
Model at 26-May-20	0.24
Model at 16-May-20	0.24
Model at 9-May-20	0.3
Model at 30-April-20	0.3
Model at 16-Apr-20	0.45

It was observed that model accuracy would be better when prediction was run with more than 101 data points. Alpha value is 0.50 which is in between 0.0 to 1.0 range. Model drawn on 16-May-20 and 26-May-20 has same MASE value indicate stable model.

4.2 Estimate the "COVID-19" Confirmed Cases for India and using Prophet R-Language library

Forecast is generated till 30-Jun-20 days using Prophet library for time series additive method. R Studio is used to generate forecast and graphs.

***TABLE. 4** NUMBER OF CONFIRMED CASES AND PREDICTED FORECAST TILL 30-JUN-20*

Day of Date	Lower Prediction Interval	Upper Prediction Interval	Confirmed Cases
30-Jun-20	265502	296539	280814
29-Jun-20	262115	291821	276489
28-Jun-20	258391	287640	272110
27-Jun-20	255439	281998	267814
26-Jun-20	250614	277098	263508
25-Jun-20	247419	272210	259211
24-Jun-20	243779	267350	254985
23-Jun-20	241477	263770	251455
22-Jun-20	236633	258926	247129
21-Jun-20	233398	253750	242751
20-Jun-20	229289	249280	238454
19-Jun-20	226169	243840	234148
18-Jun-20	221863	238622	229851
17-Jun-20	217833	234379	225626
16-Jun-20	214858	230492	222096
15-Jun-20	211223	225212	217770
14-Jun-20	207255	220392	213392
13-Jun-20	203438	215901	209095
12-Jun-20	199163	211319	204789
11-Jun-20	195278	206457	200492
10-Jun-20	191465	201572	196266
09-Jun-20	187951	197590	192736
08-Jun-20	183971	192865	188411
07-Jun-20	179995	188319	184033
06-Jun-20	176132	183756	179736
05-Jun-20	172016	179310	175430
04-Jun-20	167600	174738	171133
03-Jun-20	163773	170476	166907
02-Jun-20	160242	166527	163377
01-Jun-20	155971	162289	159051
31-May-20	151739	157759	154673
30-May-20	147466	153188	150377
29-May-20	142936	149063	146070
28-May-20	139013	144587	141773
27-May-20	134873	140216	137548

Fig. 3 shows 35 days of forecast created till 30-Jun-20.
More number of cases confirmed on Tuesday and less number of cases reported on Wednesday however there might be delay, lag in the number of cases reported on time and data entry into computer.

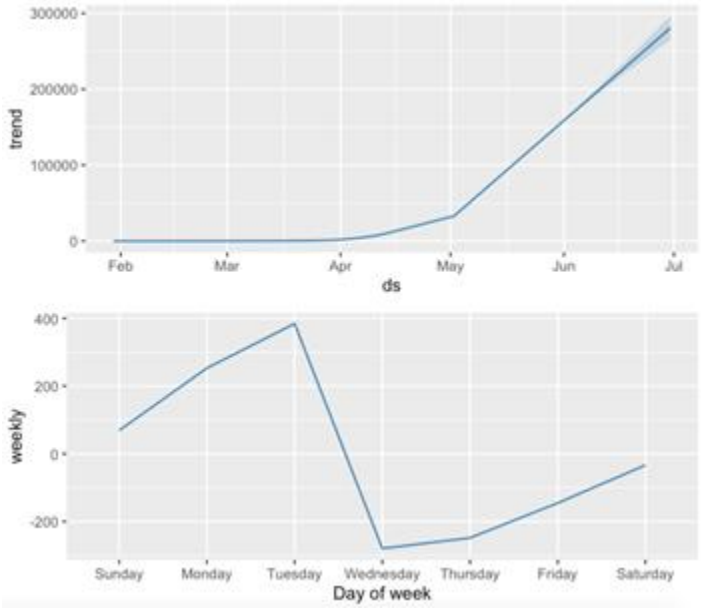

Figure 3. *Predicted forecast using R Prophet library from 26-May-20 till 30-Jun-20*

Model Accuracy

Forecast accuracy of model represented by R-squared value and p-Value of model. R-squared: 0.9962, p-value: < 0.00000000000000022, degrees of freedom :116.

Fig. 4 shows actuals vs forecast values and represent that predicted value are slightly over and under estimated than actuals but still close to linear line with high accuracy.

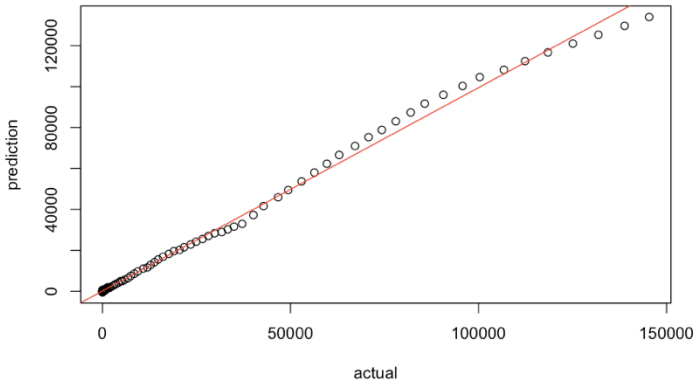

Figure 4*. Actual cases vs Predicted for confirmed cases using Prophet library*

4.2 Estimate the "COVID-19" Confirmed Cases for India and using Holt/ double exponential smoothing method in SPSS

We have used same dataset in SPSS to predict forecast with time series Holts method and Table 4 represent forecast value.

TABLE. 4 *NUMBER OF CONFIRMED CASES AND PREDICTED FORECAST TILL 30-JUN-20*

Day of Date	Lower Prediction Interval	Upper Prediction Interval	Confirmed Cases
30-Jun-20	330028	432890	381459
29-Jun-20	325445	423990	374717
28-Jun-20	320830	415121	367976
27-Jun-20	316183	406284	361234
26-Jun-20	311505	397479	354492
25-Jun-20	306794	388707	347751
24-Jun-20	302050	379967	341009
23-Jun-20	297273	371262	334267
22-Jun-20	292461	362590	327525
21-Jun-20	287615	353953	320784
20-Jun-20	282733	345351	314042
19-Jun-20	277815	336786	307300
18-Jun-20	272860	328258	300559
17-Jun-20	267867	319767	293817
16-Jun-20	262836	311314	287075
15-Jun-20	257766	302901	280334
14-Jun-20	252655	294529	273592
13-Jun-20	247503	286197	266850
12-Jun-20	242309	277908	260109
11-Jun-20	237071	269663	253367
10-Jun-20	231788	261463	246625
09-Jun-20	226458	253309	239884
08-Jun-20	221081	245203	233142
07-Jun-20	215654	237147	226400
06-Jun-20	210175	229142	219658
05-Jun-20	204641	221192	212917
04-Jun-20	199052	213298	206175
03-Jun-20	193402	205464	199433
02-Jun-20	187690	197694	192692
01-Jun-20	181909	189991	185950
31-May-20	176055	182361	179208
30-May-20	170120	174813	172467
29-May-20	164092	167358	165725
28-May-20	157948	160018	158983
27-May-20	151640	152843	152242

Fig. 5 represent predicted and confirmed cases. X axis denote weeks and days. Red color line represents actual and blue color for forecast

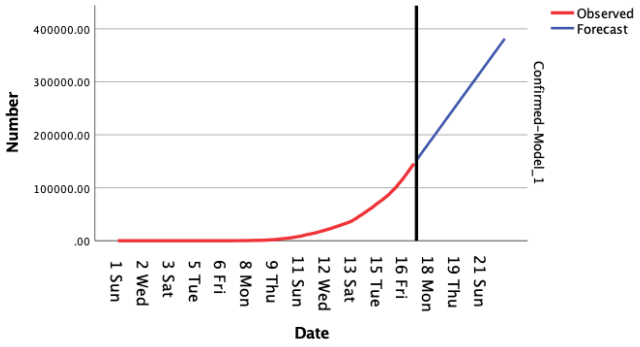

Figure 5. *Predicted forecast using time series Holt method from 26-May-20 till 30-Jun-20*

Model Accuracy

R-squared value :1.0 with 95 % confidence internal. R square value represent the perfect fit model.

TABLE. 5 *SUMMARY OF THREE MODEL FORECAST TILL 30-JUN-20*

Day of Date	Prophet library Model	Simple Exponential Smoothing	Holt Model

30-Jun-20	280814	385451	381459
29-Jun-20	276489	378588	374717
28-Jun-20	272110	371726	367976
27-Jun-20	267814	364863	361234
26-Jun-20	263508	358000	354492
25-Jun-20	259211	351137	347751
24-Jun-20	254985	344275	341009
23-Jun-20	251455	337412	334267
22-Jun-20	247129	330549	327525
21-Jun-20	242751	323686	320784
20-Jun-20	238454	316824	314042
19-Jun-20	234148	309961	307300
18-Jun-20	229851	303098	300559
17-Jun-20	225626	296235	293817
16-Jun-20	222096	289373	287075
15-Jun-20	217770	282510	280334
14-Jun-20	213392	275647	273592
13-Jun-20	209095	268784	266850
12-Jun-20	204789	261922	260109
11-Jun-20	200492	255059	253367
10-Jun-20	196266	248196	246625
09-Jun-20	192736	241333	239884
08-Jun-20	188411	234471	233142
07-Jun-20	184033	227608	226400
06-Jun-20	179736	220745	219658
05-Jun-20	175430	213882	212917
04-Jun-20	171133	207019	206175
03-Jun-20	166907	200157	199433
02-Jun-20	163377	193294	192692
01-Jun-20	159051	186431	185950
31-May-20	154673	179568	179208
30-May-20	150377	172706	172467
29-May-20	146070	165843	165725
28-May-20	141773	158980	158983
27-May-20	137548	152117	152242

5 CONCLUSION

The paper presented “COVID-19” confirmed cases in India till 31 June 2020. We believe that forecast is important factor while taking decision for the Government and private sectors. In this Analysis, we have used three time series model with assumption that the published data is accurate. The data set used from the Ministry of Health & Family Welfare and COVID 19india published through kaggle. The exponential smoothing model was applied using the Tableau tool. Exponential smoothing model accuracy was about 70%.

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