COVID 19: Real-time Forecasts of confirmed cases, active cases, and health infrastructure requirements for India and its states using the ARIMA model.

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INTERNATIONAL INSTITUTE FOR POPULATION SCIENCES, MUMBAI
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14th June 2020

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IIPS Analytical Series on COVID-19:

Paper 16: COVID 19: Real-time Forecasts of confirmed cases, active cases, and health infrastructure requirements for India and its states using the ARIMA model.

(This work has not been peer-reviewed. If you find any errors or have clarifications, please email the authors.)

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Salient Findings:

1. Our forecasts indicate that India will have an estimated 11,64,389 confirmed cases (95% CI: 996386, 1332392) and 5,16,785 active cases (95% CI: 417157, 616414) by the end of July.

2. India needs to prepare 4,39,268 isolation beds (95% CI: 354583, 523952), 51,679 ICU beds (95% CI: 41716, 61641) and 25,839 ventilators (95% CI: 20858, 30821) by the end of July.

3. Looking at the state-level, Punjab will be the least affected state with less than 500 active cases, while Maharashtra and Delhi will be the most affected states by the end of July having the highest number of active cases according to our forecasts.

4. Maharashtra will require 74,615 isolation beds (95% CI: 38239, 92393), 7,229 ICU beds (95% CI: 3589, 10870) and 3,615 ventilators (95% CI: 1794, 5435) by the end of July.

5. Delhi will require 61,450 isolation beds (95% CI: 30506, 110990), 8,778 ICU beds (95% CI: 4499, 13058) and 4,389 ventilators (95% CI: 2249, 6529) by the end of July.

6. The actual numbers can go higher than our forecasts as India has a limited testing facility and coverage, due to which a large number of cases are going undetected

COVID 19: Real-time Forecasts of confirmed cases, active cases, and health infrastructure requirements for India and its states using the ARIMA model.

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Abstract

Background: COVID-19 is an emerging infectious disease which has been declared a Pandemic by the World Health Organization (WHO) on March 11 2020. The Indian public health care system is already overstretched, and this pandemic is making things even worse. 0That is why forecasting cases for India is necessary to meet the future demands of the health infrastructure caused due to COVID-19.

Objective: Our study forecasts the confirmed and active cases for COVID-19 until July end, using time series Autoregressive Integrated Moving Average (ARIMA) model. Additionally, we estimated the number of isolation beds, Intensive Care Unit (ICU) beds and ventilators required for the growing number of COVID-19 patients.

Methods: We used ARIMA model for forecasting confirmed and active cases till the July 31. We used time-series data of COVID-19 cases in India from March 14 to June 8. We estimated the requirements for ICU beds as 10%, ventilators as 5% and isolation beds as 85% of the active cases forecasted using the ARIMA model.

Results: Our forecasts indicate that India will have an estimated 11,64,389 confirmed cases (95% CI: 996386, 1332392) and 5,16,785 active cases (95% CI: 417157, 616414) by July 31. Punjab will be the least affected state with less than 500 active cases by the end of July, while Maharashtra and Delhi will be the most affected states, having the highest number of active and confirmed cases. India needs to prepare 4,39,268 isolation beds (95% CI: 354583, 523952), 51,679 ICU beds (95% CI: 41716, 61641) and 25,839 ventilators (95% CI: 20858, 30821) by the end of July.

Conclusion: Our forecasts show an alarming situation for India, and Maharashtra and Delhi in particular. The actual numbers can go higher than our estimated numbers as India has a limited testing facility and coverage, due to which a large number of cases are going undetected.

Keywords: COVID-19, India, Forecast, ARIMA, Health Infrastructure, State-level analysis.

1. Introduction

COVID-19 is an emerging infectious disease caused by severe acute respiratory syndrome Corona Virus 2 (SARS-CoV-2). The first human cases of COVID-19 were first reported by officials in Wuhan City, China, in December 2019. Retrospective investigations by Chinese authorities have identified human cases with onset of symptoms in early December 2019. While some of the earliest known cases had a link to a wholesale food market in Wuhan, some did not (WHO, 2020). The World Health Organization (WHO) has declared the outbreak of the novel Coronavirus (COVID-19) as a pandemic on March 11 2020.

This pandemic is spreading very quickly throughout the world, and the number of confirmed cases reached 7.72 million on June 12. Globally, the recovery rate is around 50.76 percent and case fatality rate of 5.53 percent (Worldometer, June 12 2020). On June 12, India's confirmed cases of COVID-19 crossed 3 Lakhs. The recovery rate was 49.94 percent amongst COVID-19 patients. The case fatality rate of COVID-19 in India is 2.87 percent on June 12 in India (MoHFW, June 13, 8 AM). They also told that 73 percent of COVID-19 deaths in India are people with co-morbidities (Press Information Bureau 2020 c).

In India, the first positive case of COVID-19 was detected on January 30 2020, in Kerala (India Today, 2020). With the experience of the overwhelming burden of COVID-19 in Europe and China, the Government of India implemented a complete nationwide lockdown on March 25 for 21 days (Press Information Bureau 2020 a). The purpose of the nationwide lockdown was to contain the spread of the Coronavirus so that the Government could take a multi-prong strategy: add more beds in its network of hospitals, scale up the production of the testing kits for COVID-19 and personal protection equipment (PPE) for the health workers. On June 3, with respect to the health infrastructure in the country for the management of COVID-19, 952 dedicated COVID hospitals with 1,66,332 Isolation beds, 21,393 ICU beds, and 72,762 Oxygen supported beds are available. 2,391 dedicated COVID Health Centres with 1,34,945 Isolation beds; 11,027 ICU beds and 46,875 Oxygen supported beds have been operationalized. (Press Information Bureau 2020 c).

A few studies have attempted to predict numbers of confirmed and active cases at the national and state level for India to assess the burden of COVID-19 in future. Tiwari et al. (2020) made their prediction for India based on the pattern of China using a machine learning approa0ch.

They predicted that the peak of the cases for India would be attained between the third and fourth weeks of April 2020 in India. The infection was likely to be controlled by the end of May 2020. Chakraborty (2020) used a hybrid approach, based on an ARIMA and Wavelet-based forecasting model, to make short-term forecasts of the number of daily confirmed cases in Canada, France, India, South Korea, and the United Kingdom. The ARIMA model has been used in many studies for forecasting case count of epidemic diseases based on the time series modelling (Gupta and Pal 2020; Tandon et al., 2020; Kumar et al. 2020; Perone, 2020).

In India, the healthcare infrastructure is not up to the mark. The number of hospital beds per 1000 population is less than one - it is just one indicator to cite the vulnerable situation of India's health care systems (World Bank Database). Several studies from countries like China, Italy and Spain show the requirements of different healthcare facilities required to fight this pandemic. Guan et al. (2020) in his study on data regarding 1099 patients with laboratory-confirmed COVID-19 from 552 hospitals in 30 provinces, in mainland China through January 29 2020, found that 5.0% were admitted to the ICU, 2.3% who underwent invasive mechanical ventilation, and 1.4% who died. A study by Lazzerini et al. (2020) for Italy and Spain suggested that 40–55% of COVID-19 positive cases have been hospitalized, with 7–12% requiring admission to intensive care units. The COVID-19 Cases in Italy shows that 10–25% of patients will require ventilation, and some patients will need ventilation for several weeks. Remuzzi et al., (2020) find that the percentage of patients in intensive care reported daily in Italy between March 1 and March 11 2020, has consistently been between 9% and 11% of patients who are actively infected.

In the Indian scenario, a press release by PIB on May 8 stated that of the total 35,902 active cases, 4.8 per cent patients are in ICU, 1.1 per cent on ventilators and 3.3 per cent are on oxygen support (Press Information Bureau 2020 b). With the rising number of cases, it is crucial to forecast the requirements of healthcare infrastructure like isolation beds, ICU beds and ventilators at national and state level to make the respective authorities aware of the situation they might be facing shortly. In this study, we use the well-known ARIMA time-series model to forecast the confirmed and active cases for India at national and state level. Another objective of this study is to estimate the requirements of healthcare infrastructure in the future based on the forecasts of active cases.

2. Data and Methods

2.1 Data

Data on COVID-19 was obtained from the data-sharing portal covid19india.org. Information is collected on daily confirmed and active cases at the national and state level from March 14 to June 9 2020. This dataset provides excel of the patient database, which is used to build a required time-series. From this dataset, we have used cumulative confirmed and active cases for India and selected states. Selection of states is based on the criterion that states should have at least 100 confirmed cases on May 3 2020. By using this selection criterion, India and 17 other states selected which are Andhra Pradesh, Bihar, Delhi, Gujarat, Haryana, Jammu & Kashmir, Odisha, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, West Bengal.

2.2 Method

In this study, we applied the ARIMA model to our considered time series data of COVID-19 cases by using R- studio, for forecasting cumulative confirmed and active cases. This model has been preferred for the time series forecasting in various fields as the model predictions are based on different parameters. The required parameters for the ARIMA model are *(p, d, q)* which evaluate autoregressive term, integrated moving average and past lag term for stationary time series respectively. The degree of parameters p, d and q are determined based on the partial Auto-correlation function (PACF), Augmented Dickey-Fuller Test to test the stationary time series and Complete Auto-Correlation Function (ACF) respectively. These parameters help to capture overall fluctuations in earlier time-series which helps to predict the future. ARIMA has some advantages over the other models as it not only captures the overall picture in earlier trend, but it also provides a 95% confidence interval (CI) for our point estimates.

The model for forecasting future confirmed and active cases of COVID-19 cases is represented as,

$ARIMA$ (p, d, q): $X_t = \alpha 1\, X_{t-1} + \alpha 2\, X_{t-2} + \beta 1 Z_{t-1} + \beta 2\, Z_{t-2} + Z_t$ (i)

Where, $Z_t = X_t - X_{t-1}$ (ii)

Here, X_t is the predicted number of cumulative confirmed and active COVID-19 cases at t^{th} day; $\alpha 1$, $\alpha 2$, $\beta 1$ and $\beta 2$ are parameters whereas Z_t is the residual term for t^{th} day.

Finally, we estimate the requirement of health infrastructure, i.e., the requirement of Intensive care unit (ICU), Ventilator support, and isolation beds using the following equations based on forecasted active cases.

Required number of beds = Forecasted active cases at ith day*(85/100)

Required number of ICU = Forecasted active cases at ith day*(10/100)

Required number of Ventilators = Forecasted active cases at ith day*(5/100)

Based on these equations, infrastructure estimates till the mid of July.

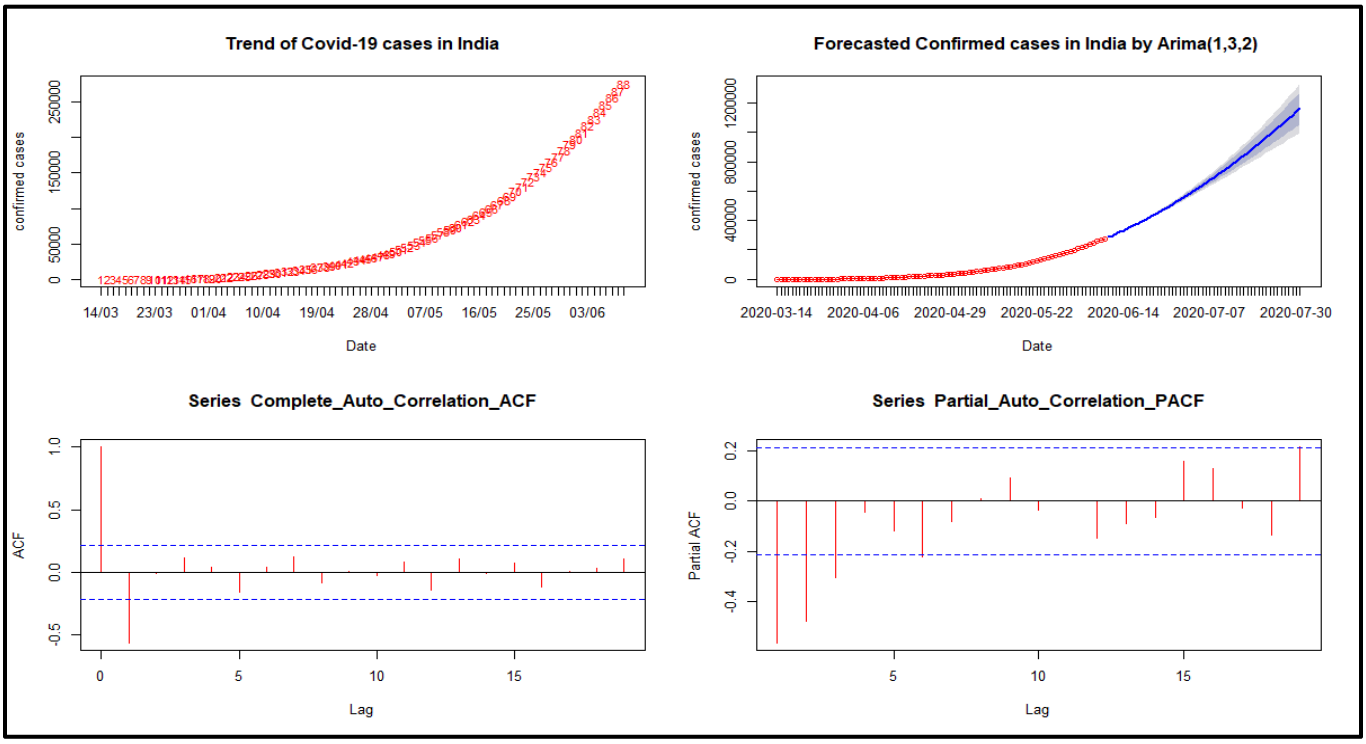
3. Results

3.1 ARIMA model fit for confirmed and active cases of COVID-19 in India

Fig 1(a) & 1(b), shows the ARIMA model fitted correlogram for the active and confirmed cases. In these figures, we see four subfigures which reveal the trend for the earlier and forecasted values for both confirmed and active cases. Forecasting based on PACF and ACF graphs helps to determine parameters p and q. Moreover, the best ARIMA model fit is considered having the lowest Akaike Information Criterion (AIC) value.

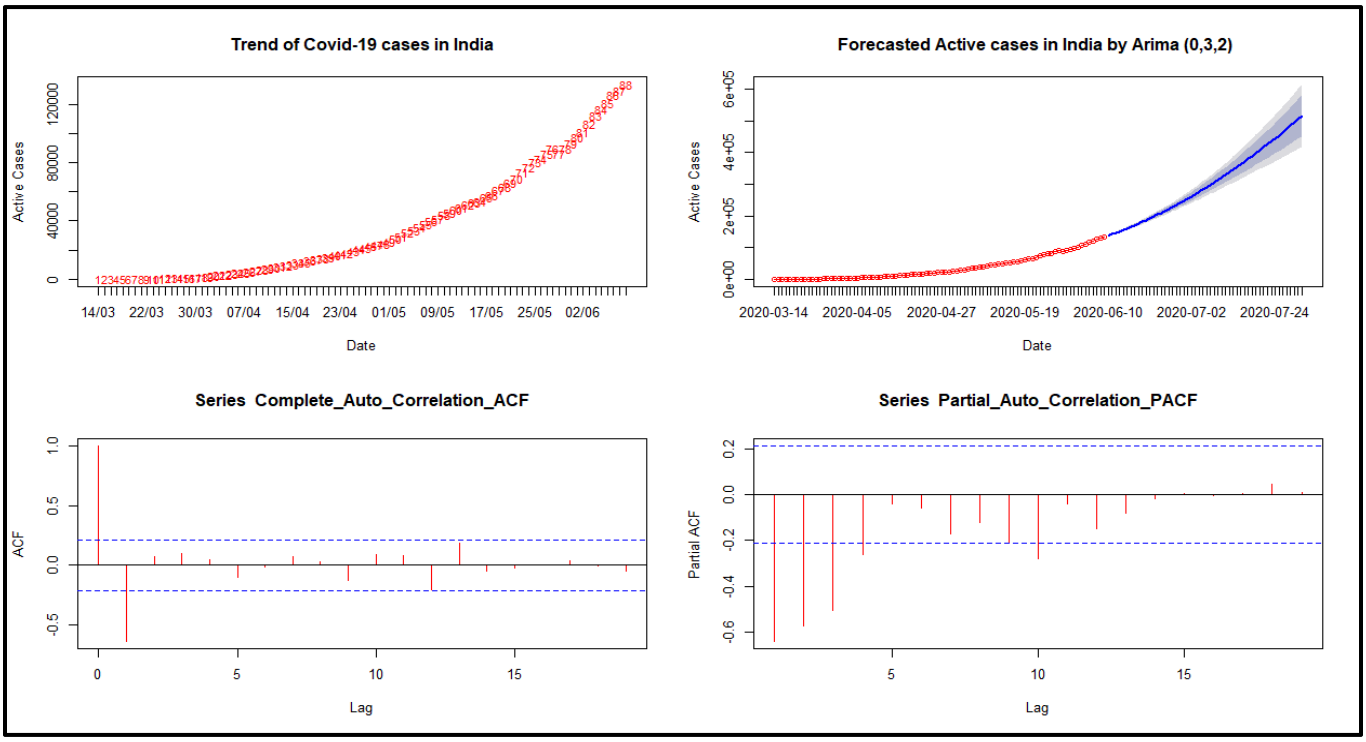
Fig 1(a) also shows the fitted model for total confirmed cases with ARIMA (1,3,2) having the lowest AIC. With the help of this model, we have predicted confirmed cases with 95% CI till July 31 2020. Similarly, for total active cases in Fig 1(b), we have a suitable model with ARIMA (0,3,2), which helps to predict active cases with 95% CI till July 31 2020.

Fig. 1(a) Correlogram and ARIMA forecast for the Confirmed COVID-19 Cases in India



Source: *Based on the author's calculations using R-studio*

Fig. 1(b) Correlogram and ARIMA Forecast for the Active COVID-19 Cases in India



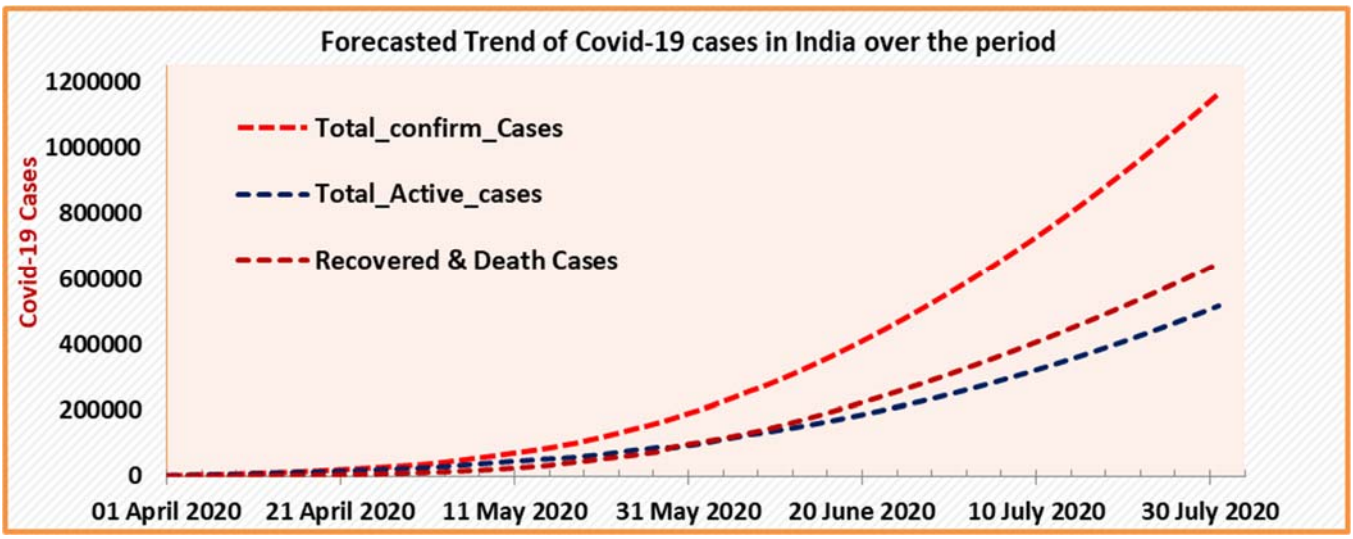
Source: *Based on the author's calculations using R-studio*

3.2 Forecasted Confirmed and active cases of COVID-19 for India:

The analysis result for India in **Table 1 and Fig. 2** shows the total confirmed and active cases for India. It has observed that with time, confirmed cases will increase at a faster rate. According to our forecasts, India will be having 5,57,247 confirmed cases (95% CI: 535355, 579139) at June 30, 8,22,541 confirmed cases (95% CI: 751916, 893167) at July 15 and 11,64,389 confirmed cases (95% CI: 996386, 1332392) at the end of July.

Similarly, based on our forecasts for active cases for India, we found that active cases for India will be 2,48,029 (95% CI: 229968, 266090) at June 30, 3,63,213 active cases (95% CI: 317021, 409404) at July 15 and 5,16,785 active cases (95% CI: 417157, 616414) will occur at the end of July.

Fig.2 Trend of Forecasted Confirm and Active COVID-19 Cases over the Period in India



Source: Based on the author's calculations using R-studio

3.3 Forecasted Confirmed cases of COVID-19 for the selected states of India:

Table 2, shows the forecast of confirmed for selected states of India on June 30, July 15 and July 31. Our forecasts show that that confirmed cases for states vary a lot from one state to another. Our forecasts for June 30 for confirmed cases show that Punjab and Kerala will have around 4000 confirmed cases. However, states like Maharashtra 1,46,377 confirmed cases (95% CI: 127709, 165045), Tamil Nadu 70,299 confirmed cases (95% CI: 61159, 79439),

Delhi 63,589 confirmed cases (CI: 53537, 73642) & Gujarat 31,032 confirmed cases (95% CI: 27376, 34688) would have a high number of confirmed cases among states at the June 30.

On July 15, Kerala and Punjab will be the least affected states having around 5000 confirmed cases based on our forecasts. Though, states like Maharashtra 1,87,044 confirmed cases (95% CI: 133069, 241019), Tamil Nadu 95,574 confirmed cases (95% CI: 75352, 115796), Delhi 92,868 confirmed cases (95% CI: 67651, 118084) & Gujarat 38,166 confirmed cases (95% CI: 30548, 45784) will have highest confirmed cases among states on 15th July.

On July 31, Punjab and Kerala will be the least affected state with less than 7000 confirmed cases. However, other states like Maharashtra (2,31,306 confirmed cases (95% CI: 113430, 349182)), Tamil Nadu (1,22,534 confirmed cases (95% CI: 87648, 157420)), Delhi (1,29,812 confirmed cases (95% CI: 80428, 179195)) & Gujarat (45,776 confirmed cases (95% CI: 32985, 58567)) will have highest number of confirmed cases among states at 31st July.

3.4 Forecasted active cases of COVID-19 for the selected states of India:

Table 3 shows the state-wise active cases for India. On June 30, Punjab will be the least having least number of active cases (around 500 active cases based on our forecasts). However, states like Maharashtra (62,194 active cases (95% CI: 47155, 77233)), Delhi (37,172 active cases (95% CI: 28453, 45891)) & Tamil Nadu (35,559 active cases (95% CI: 22477, 48641)) will have highest number of active cases among states on 30th June.

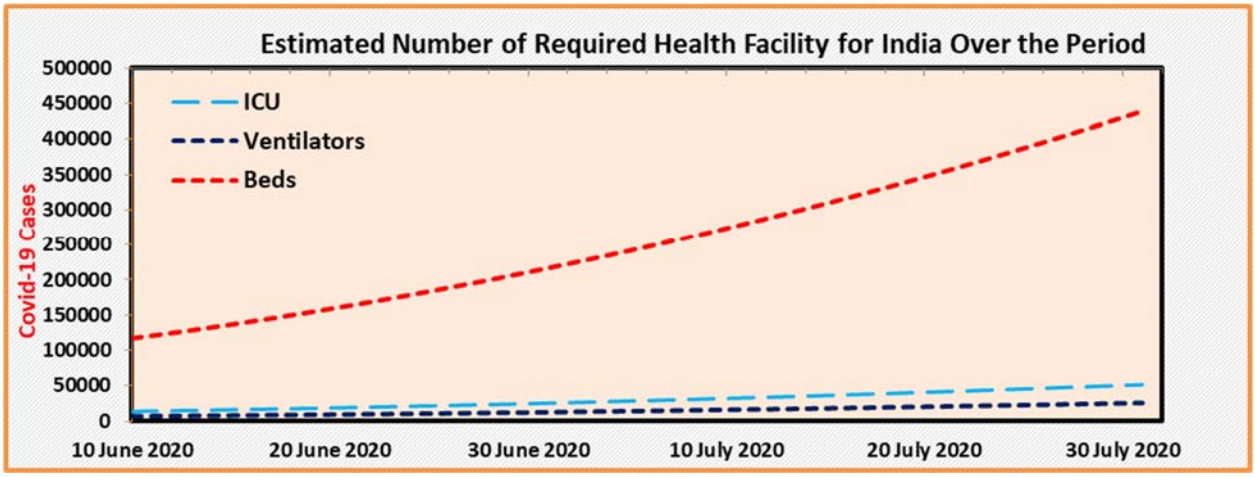
On July 15, Punjab will be the least having least number of active cases (around 500 active cases based on our forecasts). However, states like Maharashtra (74,575 active cases (95% CI: 47221, 101930), Delhi (53,029 active cases (95% CI: 32933, 73125) & Tamil Nadu (49,317 active cases (95% CI: 20641, 77993) will have the highest number of active cases among states on July 15.

On July 31, Punjab will be having the least number of active cases (around 500 active cases based on our forecasts). However, states like Maharashtra (87,782 active cases (95% CI: 44987, 130577), Tamil Nadu (63,992 active cases (95% CI: 14723, 113261) & Delhi (72,294 active cases (95% CI: 35890, 108697) will have the highest number of active cases among states on July 31.

3.5 Estimates of required healthcare infrastructure for India

Table 4, 5, 6 and **Fig. 3** show the required number of isolation beds, ICU beds and ventilators for active cases of COVID-19 on June 30, July 15, and July 31, respectively for India. The total number of isolation beds required is 2,10,825 (95% CI: 195473, 226177). It also shows that 24,803 ICU beds (95% CI: 22997, 26609) and 12,401 ventilators (95% CI: 11498, 13305) will be required in India by June 30. On July 15, the total number of isolation beds required for India is 3,08,731 (95% CI: 269468, 347994). It also shows that 36,321 ICU beds (95% CI: 31702, 40940) and 18,161 ventilators (95% CI: 15851, 20470) will be required in India by July 15. India will require 4,39,268 isolation beds (95% CI: 354583, 523952), 51,679 ICU beds (95% CI: 41716, 61641) and 25839 ventilators (95% CI: 20858, 30821) by 31st July.

Fig.3 Estimates of required healthcare infrastructure over the Period in India, 2020



Source: Based on the author's calculations using R-studio

3.6 Estimates of required healthcare infrastructure at state-level

Table 4, 5, and 6 show the required number of isolation beds, ICU beds and ventilators for patients that will be suffering from COVID-19 on June 30, July 15, and July 31 respectively for Indian states. The overall picture for estimates shows a huge variation across the states. By June 30, Punjab will recover most of the active cases and requires less than 500 isolation beds, around 50 ICU beds and 25 ventilator beds according to our point estimates. While, on the other hand, Maharashtra, with the largest number of active cases shows an alarming situation and will

require 52,865 isolation beds (95% CI: 40081, 65648), 6,219 ICU beds (95% CI: 4715, 7723) and 3,110 ventilators (95% CI: 2358, 3862).

At the mid of July, Punjab will recover most of the active cases and requires less than 500 isolation beds, around 50 ICU beds and 26 ventilator beds according to our point estimates. While, Maharashtra, will require 63,389 isolation beds (95% CI: 40137, 86640), 7,458 ICU beds (95% CI: 4722, 10193) and 3,729 ventilators (95% CI: 2361, 5096).

At the end of July, Punjab will recover most of the active cases and requires less than 500 isolation beds, around 50 ICU beds and 26 ventilator beds according to our point estimates. While, on the other hand, Maharashtra, with the largest number of active cases will require 74,615 isolation beds (95% CI: 38239, 110990), 8,778 ICU beds (95% CI: 4499, 13058) and 4389 ventilators (95% CI: 2249, 6529) will be required by July 31.

4. Discussion and Conclusion

Our current forecasts for confirmed and active cases are in line with the actual number of cases. On June 12, India has 3,09,603 confirmed cases, while our forecasts suggested 3,09,412 confirmed cases (95% CI: 307350, 311474). India had 1,46,460 active cases on June 12, while our forecasts suggested that India will have 1,46,587 active cases (95% CI: 143197, 149978). Our results also show that daily confirmed cases would increase at a faster pace as around July end India will be getting around 35,000 daily confirmed cases. By July 31, we forecast that the total confirmed cases will be around 11.64 lakhs, whereas total active cases will be close to 5.16 lakhs based on our point estimates for India. Maharashtra will be the most affected state even at the July 31 with 2.31 Lakh confirmed cases and 0.87 Lakh active cases while Punjab will be least affected having 6524 confirmed cases and only 500 active cases based on our point estimates. The total number of isolation beds required for India is 4,39,268 (95% CI: 354583, 523952) on July 31. Our estimates also show that 51,679 ICU beds (95% CI: 41716, 61641) and 25,839 ventilators (95% CI: 20858, 30821) will be required in India by July 31. When it comes to states, Maharashtra will be the most affected state and will require 74,615 isolation beds (95% CI: 38239, 110990), 8,778 ICU beds (95% CI: 4499, 13058) and 4389 ventilators (95% CI: 2249, 6529).

On June 3, with respect to the health infrastructure in the country for the management of COVID-19, 952 dedicated COVID hospitals with 1,66,332 Isolation beds, 21,393 ICU beds, and 72,762 Oxygen supported beds are available. 2,391 dedicated COVID Health Centres with 1,34,945 Isolation beds; 11,027 ICU beds and 46,875 Oxygen supported beds have also been operationalized. Based on the current preparedness of the Indian healthcare infrastructure, we recommend that India should keep increasing its health infrastructure at a fast pace to avoid shortage. The health infrastructure stress will likely be acute in high-burden states, led by Maharashtra, Tamil Nadu and Delhi as they have more than 10,000 active cases on June 2. In particular, Maharashtra is the most affected state with around 40,000 active cases as on June 2. On May 29, BrihanMumbai Municipal Corporation (BMC) reported that almost all intensive care unit (ICU) beds for COVID-19 patients were occupied in Mumbai. They also tell that the city is already using 72% of the total 373 ventilators available for COVID-19 treatment (Mint, 2020). This shows an alarming situation for Maharashtra and in particular, Mumbai. The most affected state Maharashtra needs to prepare at least 1 lakh isolation beds, 12,000 ICU beds and 6000 ventilators by July 15 to fight this pandemic efficiently.

Our forecasts are based on the data which grossly under-reported the cases as found by many studies for India. Rao *et al.,* (2020), projected that India might be detecting 1 out of 4 cases of COVID-19 based on his mathematical model. Another study by (Goli and James, 2020) also find that India is detecting just 3.6% of the total number of infections of COVID-19 with a huge variation across its states. They also suggest that India must increase its testing capacity and go for widespread testing to know the real picture of the pandemic. Lack of coverage of testing is not revealing the true prevalence of COVID-19. (Subramanian and James, 2020) suggested that for detection of the true prevalence of COVID-19 infections in the country, India can adopt the well-established National Family Health Survey (NFHS) framework as a solution to ascertain the true prevalence of COVID-19. Understanding the urgency of the situation, ICMR conducted a serosurvey in early May. The serosurvey aimed to estimate the fraction of the general population who has been infected with SARS-CoV-2. In Part-I of the survey, a total of 28,595 households were visited in the 83 districts surveyed for this purpose. Blood samples, along with data, was collected from 26,400 individuals in the survey. The results of Part-I of the survey revealed that 0.73% population in the districts surveyed had evidence of past exposure to SARS-CoV-2. It has also been found that risk of infection is slightly higher in urban areas (1.09), higher in urban

slums (1.89) in comparison to rural areas (Press Information Bureau 2020 d). The data issues of COVID-19 such as under-reporting, lack of coverage etc. results in an underestimation of the cases, which in turn will lead to underestimation of the forecasts in our study.

Our forecasts show an alarming situation for India in the future. In coming months, the actual numbers can go higher than our forecasts of confirmed cases, active cases and healthcare infrastructure as migrant workers are returning home in large numbers currently in large numbers (Tyagi *et al.,* 2020). Currently, India has lifted lockdown with restrictions applying only on the containment zones. This will lead to a surge in the number of daily confirmed and active cases. The requirement of isolation beds, ICUs and ventilators will also be increased in that scenario. So, India and its majorly affected states like Maharashtra, Delhi, Tamil Nadu and Gujarat need to be well prepared for the pandemic challenge in future and focus on increasing their healthcare infrastructure, and other states should also remain alert till the pandemic completely recedes.

Acknowledgements: Authors would like to thank Prof. K.S. James, Director and Senior Professor, International Institute for Population Sciences (IIPS), Mumbai, for his suggestions, and finalizing this study for IIPS COVID-19 Study Series.

Table 1: Forecast of Confirmed and Active Cases of COVID-19 for India from June 10 to July 31 2020, India

Date	Confirmed Cases	95% Confidence Interval		Active Cases	95% Confidence Interval		Death & Recovered (%)
	Point Estimates	Lower	Upper	Point Estimates	Lower	Upper	
10 June 2020	286756	285883	287629	137793	135906	139679	52
12 June 2020	309412	307350	311474	146587	143197	149978	53
14 June 2020	333137	330015	336258	155877	151284	160470	53
16 June 2020	357826	353560	362091	165663	159899	171426	54
18 June 2020	383466	377845	389086	175943	168947	182939	54
20 June 2020	410056	402781	417330	186719	178373	195066	54
22 June 2020	437595	428305	446885	197991	188134	207847	55
24 June 2020	466084	454363	477804	209757	198200	221314	55
26 June 2020	495522	480915	510129	222019	208543	235496	55
28 June 2020	525910	507923	543896	234776	219139	250414	55
30 June 2020	557247	535355	579139	248029	229968	266090	55
02 July 2020	573272	549221	597322	254841	235464	274218	56
04 July 2020	606033	577235	634831	268837	246609	291064	56
06 July 2020	639744	605604	673885	283328	257945	308710	56
08 July 2020	674405	634301	714508	298314	269458	327170	56
10 July 2020	710015	663303	756726	313796	281134	346457	56
12 July 2020	746574	692588	800560	329773	292961	366584	56
14 July 2020	784083	722133	846033	346245	304927	387563	56
16 July 2020	822541	751916	893167	363213	317021	409404	56
18 July 2020	861949	781916	941981	380676	329232	432119	56
20 July 2020	902306	812115	992498	398634	341550	455718	56
22 July 2020	943613	842491	1044735	417087	353964	480210	56
24 July 2020	985869	873026	1098712	436036	366466	505607	56
26 July 2020	1029075	903701	1154449	455481	379045	531916	56
28 July 2020	1073230	934498	1211962	475420	391693	559148	56
30 July 2020	1118335	965399	1271271	495855	404400	587311	56
31 July 2020	1164389	996386	1332392	516785	417157	616414	56

Source: *Based on the author's calculations using R-studio*

Table 2: Forecast of Confirmed Cases of COVID-19 for India and its States on June 30, July 15 and July 31 2020, India

Dates	June end			July mid			July end		
STATES	PE	95% CI		PE	95% CI		PE	95% CI	
		Lower	Upper		L.B.	UB		L.B.	UB
India	557247	535355	579139	822541	751916	893167	1164389	996386	1332392
Andhra Pradesh	9169	7947	10392	12125	9476	14774	15278	10750	19807
Bihar	9653	7964	11342	12652	9082	16222	15850	9817	21884
Delhi	63589	53537	73642	92868	67651	118084	129812	80428	179195
Gujarat	31032	27376	34688	38166	30548	45784	45776	32985	58567
Haryana	12867	10094	15639	18336	12235	24437	24171	13670	34671
Jammu & Kashmir	8702	6748	10657	11814	7840	15788	15133	8538	21728
Karnataka	10257	6976	13538	13329	6128	20529	16605	4225	28984
Kerala	4014	3250	4778	5382	3705	7059	6841	3959	9724
Madhya Pradesh	14210	12196	16223	17323	13177	21469	20644	13724	27565
Maharashtra	146377	127709	165045	187044	133069	241019	231306	113430	349182
Odisha	5894	4922	6865	7860	5828	9893	9958	6540	13377
Punjab	4043	1262	6825	5165	37	11592	6524	9	18138
Rajasthan	17808	15751	19865	22498	18088	26909	27502	19998	35005
Tamil Nadu	70299	61159	79439	95574	75352	115796	122534	87648	157420
Telangana	6988	5555	8422	9184	6068	12301	11527	6192	16861
Uttar Pradesh	19666	17152	22179	25616	20281	30951	31963	22929	40998
West Bengal	18308	15133	21482	25062	17140	32983	32276	17687	46865

Source: *Based on the author's calculations using R-studio*

Table 3: Forecast of Active Cases of COVID-19 for India and its States on 30th June, July 15 and July 31, 2020, India

Dates	June end			July mid			July end		
STATES	PE	95% CI		PE	95% CI		PE	95% CI	
		Lower	Upper		L.B.	UB		L.B.	UB
India	248029	229968	266090	363213	317021	409404	516785	417157	616414
Andhra Pradesh	4974	3504	6445	6972	3859	10086	9104	3838	14370
Bihar	3493	771	6215	4206	0	10333	5071	0	16017
Delhi	37172	28453	45891	53029	32933	73125	72294	35890	108697
Gujarat	5643	1882	9403	5649	273	11024	5649	0	12343
Haryana	6925	1243	12607	8063	0	26632	7987	0	51133
Jammu & Kashmir	6778	5200	8356	9504	5987	13022	12412	6318	18507
Karnataka	5057	3073	7041	6343	2263	10423	7715	907	14523
Kerala	2641	1890	3392	3643	1986	5300	4712	1856	7568
Madhya Pradesh	3249	1749	4749	3684	1437	5931	4149	1201	7098
Maharashtra	62194	47155	77233	74575	47221	101930	87782	44987	130577
Odisha	1306	733	1879	1528	442	2613	1764	26	3502
Punjab	527	0	2355	525	0	2987	500	0	3518
Rajasthan	3468	2176	4760	3944	2105	5783	4452	2086	6819
Tamil Nadu	35559	22477	48641	49317	20641	77993	63992	14723	113261
Telangana	3468	2176	4760	3944	2105	5783	4452	2086	6819
Uttar Pradesh	7250	4911	9589	9311	4436	14185	11509	3324	19693
West Bengal	10245	8229	12262	14039	9461	18618	18086	10090	26082

Table 4: Forecast of Active Cases of COVID-19 and Required Health Infrastructure for India and its States on June 30, 2020, India

STATES	Active Cases	95% CI		ICU	95% CI		Ventilator	95% CI		Beds	95% CI	
	PE	LB	UB	PE	LB	UB	PE	LB	UB	PE	LB	UB
India	248029	229968	266090	24803	22997	26609	12401	11498	13305	210825	195473	226177
Andhra Pradesh	4974	3504	6445	497	350	644	249	175	322	4228	2978	5478
Bihar	3493	771	6215	349	77	621	175	39	311	2969	655	5282
Delhi	37172	28453	45891	3717	2845	4589	1859	1423	2295	31596	24185	39007
Gujarat	5643	1882	9403	564	188	940	282	94	470	4796	1600	7993
Haryana	6925	1243	12607	692	124	1261	346	62	630	5886	1056	10716
Jammu & Kashmir	6778	5200	8356	678	520	836	339	260	418	5762	4420	7103
Karnataka	5057	3073	7041	506	307	704	2529	154	352	4299	2612	5985
Kerala	2641	1890	3392	264	189	339	132	95	170	2245	1607	2883
Madhya Pradesh	3249	1749	4749	325	175	475	162	87	237	2761	1486	4036
Maharashtra	62194	47155	77233	6219	4715	7723	3110	2358	3862	52865	40081	65648
Odisha	1306	733	1879	131	73	188	65	37	94	1110	623	1597
Punjab	527	0	2355	53	0	236	26	0	118	448	0	2002
Rajasthan	3468	2176	4760	347	218	476	173	109	238	2948	1849	4046
Tamil Nadu	35559	22477	48641	3556	2248	4864	1778	1124	2432	30225	19105	41345
Telangana	3468	2176	4760	347	218	476	173	109	238	2948	1849	4046
Uttar Pradesh	7250	4911	9589	725	491	959	362	246	479	6162	4174	8151
West Bengal	10245	8229	12262	1025	823	1226	512	411	613	8708	6994	10422

Source: *Based on the author's calculations using R-studio*

Table 5: Forecast of Active Cases of COVID-19 and Required Health Infrastructure for India and its States on July 15, 2020, India

STATES	Active Cases	95% CI		ICU	95% CI		Ventilators	95% CI		Beds	95% CI	
	PE	LB	UB	PE	LB	UB	PE	LB	UB	PE	LB	UB
India	363213	317021	409404	36321	31702	40940	18161	15851	20470	308731	269468	347994
Andhra Pradesh	6972	3859	10086	697	386	1009	349	193	504	5927	3280	8573
Bihar	4206	0	10333	421	0	1033	210	0	517	3575	0	8783
Delhi	53029	32933	73125	5303	3293	7313	2651	1647	3656	45075	27993	62156
Gujarat	5649	273	11024	565	27	1102	282	14	551	4801	232	9371
Haryana	8063	0	26632	806	0	2663	403	0	1332	6854	0	22637
Jammu & Kashmir	9504	5987	13022	950	950	-950	475	299	651	8079	5089	11069
Karnataka	6343	2263	10423	634	226	1042	3172	113	521	5392	1924	8860
Kerala	3643	1986	5300	364	199	530	182	99	265	3097	1688	4505
Madhya Pradesh	3684	1437	5931	368	144	593	184	72	297	3132	1221	5042
Maharashtra	74575	47221	101930	7458	4722	10193	3729	2361	5096	63389	40137	86640
Odisha	1528	442	2613	153	44	261	76	22	131	1299	376	2221
Punjab	525	0	2987	53	0	299	26	0	149	448	0	2539
Rajasthan	3944	2105	5783	394	211	578	197	105	289	3353	1790	4916
Tamil Nadu	49317	20641	77993	4932	2064	7799	2466	1032	3900	41919	17545	66294
Telangana	3944	2105	5783	394	211	578	197	105	289	3353	1790	4916
Uttar Pradesh	9311	4436	14185	931	444	1418	466	222	709	7914	3771	12057
West Bengal	14039	9461	18618	1404	946	1862	702	473	931	11933	8042	15825

Source: *Based on the author's calculations using R-studio*

Table 6: Forecast of Active Cases of COVID-19 and Required Health Infrastructure for India and its States on July 31, 2020, India

STATES	Active Cases	95% CI		ICU	95% CI		Ventilators	95% CI		Beds	95% CI	
	PE	LB	UB	PE	LB	UB	PE	LB	UB	PE	LB	UB
India	516785	417157	616414	51679	41716	61641	25839	20858	30821	439268	354583	523952
Andhra Pradesh	9104	3838	14370	910	384	1437	455	192	718	7738	3262	12214
Bihar	5071	0	16017	507	0	1602	254	0	801	4310	0	13614
Delhi	72294	35890	108697	7229	3589	10870	3615	1794	5435	61450	30506	92393
Gujarat	5649	0	12343	565	0	1234	282	0	617	4802	0	10492
Haryana	7987	0	51133	799	0	5113	399	0	2557	6789	0	43463
Jammu & Kashmir	12412	6318	18507	1241	632	1851	621	316	925	10550	5370	15731
Karnataka	7715	907	14523	771	91	1452	3857	45	726	6558	771	12344
Kerala	4712	1856	7568	471	186	757	236	93	378	4005	1578	6433
Madhya Pradesh	4149	1201	7098	415	120	710	207	60	355	3527	1021	6033
Maharashtra	87782	44987	130577	8778	4499	13058	4389	2249	6529	74615	38239	110990
Odisha	1764	26	3502	176	3	350	88	1	175	1499	22	2976
Punjab	500	0	3518	53	0	352	26	0	176	448	0	2990
Rajasthan	4452	2086	6819	445	209	682	223	104	341	3785	1773	5796
Tamil Nadu	63992	14723	113261	6399	1472	11326	3200	736	5663	54393	12515	96272
Telangana	4452	2086	6819	445	209	682	223	104	341	3785	1773	5796
Uttar Pradesh	11509	3324	19693	1151	332	1969	575	166	985	9782	2826	16739
West Bengal	18086	10090	26082	1809	1009	2608	904	505	1304	15373	8577	22170

Source: *Based on the author's calculations using R-studio*

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APPENDIX

Fig.4 Forecast of Confirmed cases of COVID-19 for Indian States, 2020

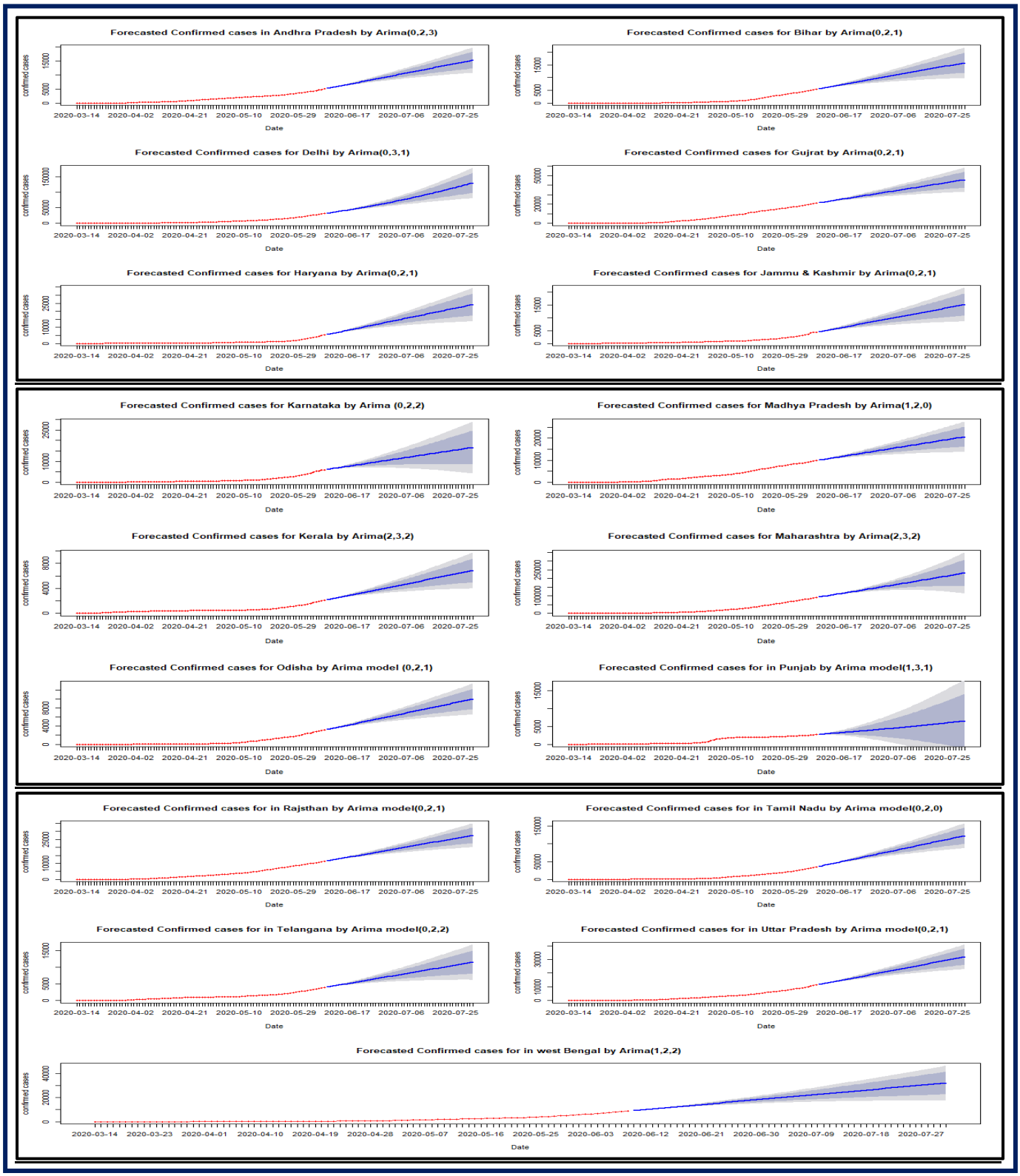
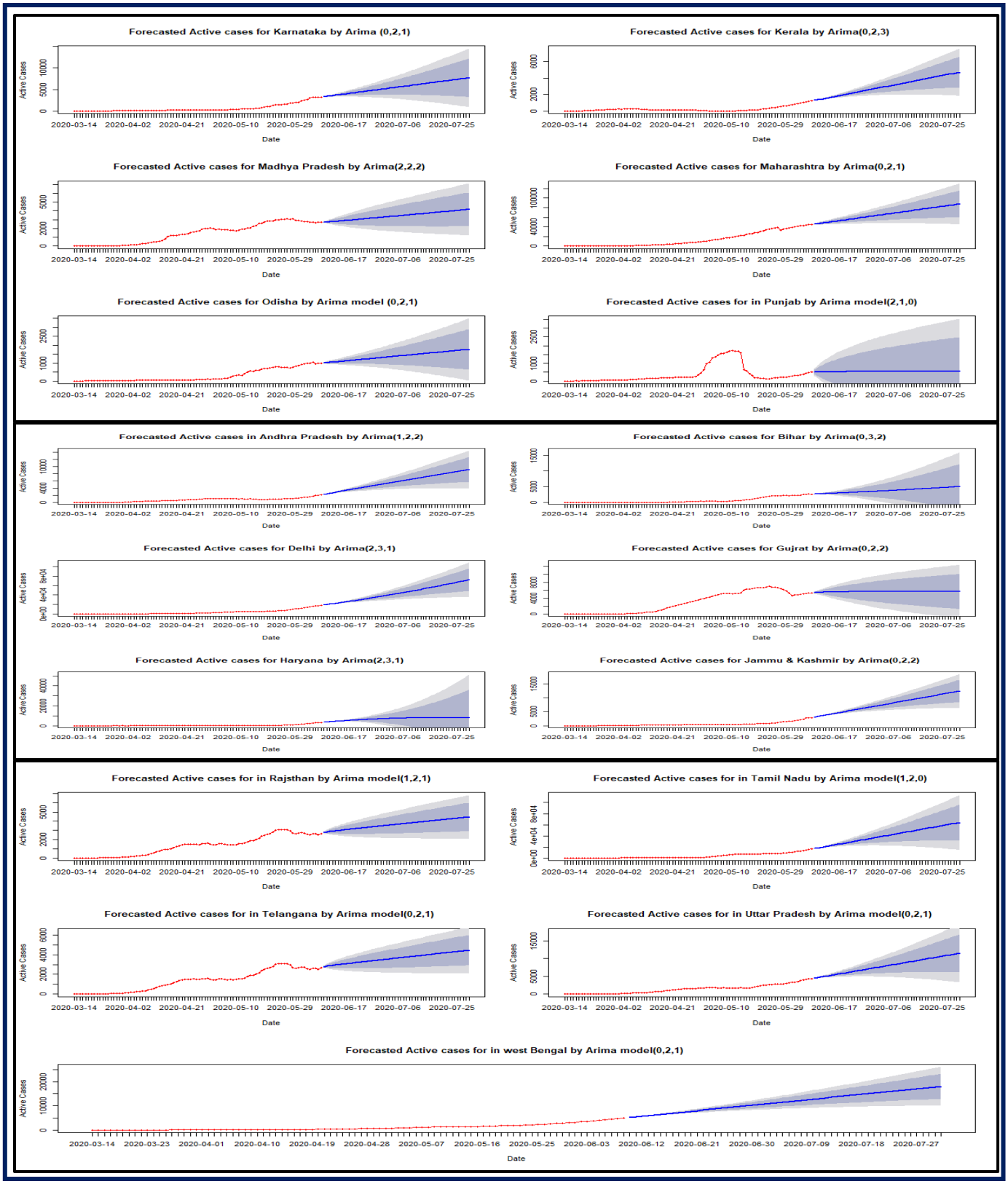


Fig.5 Forecast of Active cases of COVID-19 for Indian States, 2020



Source: *Based on the author's calculations using R-studio*

Fig.6 Trends for Future Requirements of health infrastructure for active Cases of COVID-19 in India, 2020