Omicron Projections based on South Africa

IISc–ISI Model*

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We model the spread of the COVID-19 virus for Indian states using a simple compartmental model. As noted by data uploaded in GISAID the dominant variant (though not all) among the sequenced has been the Omicron variant. Thus the recent surge may be viewed as being driven by the Omicron variant. Our entire analysis is based on the spread of Omicron variant in South Africa during the weeks 47–52 of 2021. We use the same data to provide the estimated requirements of hospital beds and numbers among those that will require intensive ventilation.

We use a compartmental SEIR–model with vaccinations and immunity waning as done in [1]. The key parameter in this model is the contact rate β that models the transmissibility of the virus. We first calibrate this model on the reported cases from South Africa during the Delta wave (15 May – 15 June 2021) and the Omicron wave (15 November – 12 December 2021) to compute the contact rates for the Delta and Omicron variants. We calculate the ratio of the Omicron's calibrated contact rate to that of the Delta's. This is the transmission advantage of Omicron compared to Delta, which we assume is applicable to the Indian population as well. We then apply this factor to the calibrated contact rates for the Indian states during the Delta wave (15 March – 30 April 2021) and run the projections forward for the Omicron variant.

The results from this model are available online at:

`https://www.isibang.ac.in/~athreya/incovid19/omicron.php`.

We shall now proceed to explain the model in more detail after which we describe the calibration methodology used, and how we obtain future projections. This is done so that others can critique our methodology. We conclude the note with the methodology used for estimating the requirements of ICU beds and hospital beds.

Model: We consider a population consisting of N individuals. This population is divided into five compartments: Susceptible (S), Exposed (E), Infected (I), Recovered (R), and Vaccinated (V). These compartments evolve over time based on the interaction among the individuals. The key parameter that governs the evolution is the contact rate β; this is the mean number of effective contacts between a tagged individual and the rest of the population. Given this parameter, the change in the number of exposed population at time t is modeled as

$$\frac{\Delta E(t)}{\Delta t} = \beta S(t)\frac{I(t)}{N} - \alpha E(t), \tag{1}$$

where $1/\alpha$ is the mean incubation period (assumed to be 5.8 days, but there seems to be some evidence that it is shorter). The rest of the states evolve according to the following dynamics:

$$\frac{\Delta S(t)}{\Delta t} = -\beta S(t)\frac{I(t)}{N} - \varepsilon\frac{\Delta V(t-\delta)}{\Delta t} + \frac{\Delta W(t)}{\Delta t}, \tag{2}$$

$$\frac{\Delta I(t)}{\Delta t} = \alpha E(t) - \gamma I(t), \tag{3}$$

$$\frac{\Delta R(t)}{\Delta t} = \gamma I(t) - \frac{\Delta W(t)}{\Delta t}. \tag{4}$$

Here, $1/\gamma$ is the mean recovery time (assumed to be 5 days), $\Delta V(t)$ is the number of individuals vaccinated on day t, δ is the time after which an individual gains immunity from vaccination (assumed to be 14 days),

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ε is the vaccine efficacy factor (assumed to be an optimistic 66%, 14 days after the first dose), and $\Delta W(t)$ models immunity waning.

To account for the asymptomatic and undetected infections, we consider the cases to infections ratio (CIR). This is usually available from serosurveys, e.g., see [2] for a serosurvey conducted in Karnataka, India. The CIR in Karnataka districts were estimated to be at most 27 [2]. The reported daily cases from the model is the time series $\Delta I(\cdot)/\mathrm{CIR}$.

South Africa Calibration: We now detail the methodology used for calibration of the contact rates. Towards this, we consider the reported cases in South Africa during the Delta and Omicron waves and do a calibration of the contact rates for the Delta and the Omicron variants.

To calibrate the contact rate during the beginning of the Delta wave, we initialize the model on 15 April 2021. The initial recovered population is set to 20%, and the CIR is set to 15 [3]. The initial vaccinations are based on the cumulative vaccinations in South Africa until 15 April 2021. We also assume 0.01% of active infections on 15 April 2021. The rest of the population is assumed to be susceptible to the Delta variant on 15 April 2021. With these initial conditions, we calibrate the contact rates to match the output of the model with that of the reported cases during 15 May 2021 – 15 June 2021. This calibration results in a contact rate of $\beta = 0.417$; this corresponds to a basic reproduction number of 2.09.

We next calibrate for the contact rate during the beginning of the Omicron wave. We initialize the model on 20 October 2021. Since the rise in the number of cases depends on the vaccinations and past infections, we treat the initial susceptible population as a parameter. To start with, we assume that everyone is susceptible to the Omicron variant, irrespective of the vaccination and past infection status. Starting with 500 initial infections on 20 October 2021, we calibrate the model to match the number of reported cases during 20 November – 12 December 2021. This leads to a contact rate of 0.587, which 1.41 times that of the calibrated contact rate during the Delta wave. We then change the initial susceptible population to 60% and 30% and repeat the calibration. We find that the contact rates of these scenarios are 2.6 and 5.1 times that of the corresponding calibrated contact rate for the Delta wave.

Future Projections: To project the number of COVID-19 cases in Indian state, we employ the following methodology. We first calibrate the contact rate to match the reported cases during the increasing phase of the Delta wave in India (15 March – 30 April 2021). To predict the cases in the future, we initialize the model with 20 cases in every state. We multiply the calibrated contact rate for the Delta wave with the factors obtained from the South Africa study and run the model until March 2021. Finally, we do a time alignment on the simulated curves so that we match the number of reported cases during the past one week[1]. We consider three scenarios as before: 100%, 60% and 30% susceptibility of the population to the virus.

To project the number of hospital beds, we consider South Africa data during the weeks 47–51 of 2021 [4]. Based on the number of reported cases and hospitalisations, South Africa data indicates about 7% of the reported cases require hospitalisation. Among the hospitalised, we find that 5% require ventilator support.

Whenever we update the model, we also report the mean-squared error from the previous model projection for all the three scenarios.

References

[1] A. Adiga et al., Strategies to Mitigate COVID-19 Resurgence Assuming Immunity Waning: A Study for Karnataka, India, medrXiv preprint, 2021.

[2] M.R.Padma et al., Second round statewide survey for estimation of the burden of active infection and anti-SARS-CoV-2 IgG antibodies in the general population of Karnataka, India', International Journal of Infectious Diseases – Regions, 2022.

[3] Mutevedzi et al., "Estimated SARS-CoV-2 infection rate and fatality risk in Gauteng Province, South Africa: a population-based seroepidemiological survey", International Journal of Epidemiology, October 2021.

[4] NICD National COVID-19 Hospital Surveillance, January 2022.

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[1] This time-alignment procedure will be carried out on a weekly basis as new data points arrive.