More Detailed Modelling of COVID-19

Introduction

Our objective is to model the different phases of the COVID-19 pandemic in India using the SEIRV model. The COVID-19 disease has spread across the globe and caused millions of deaths, and the pandemic resulted in significant social and economic disruption. Vaccines have been created in record time and are being administered but problems like immunity waning, and new and more potent variants of the coronavirus have continued to cause new waves of infections every now and then in different parts of the world. Our aim is to build a computational model that predicts the future spread of the disease, and to study the different parameters involved in the model, which would be helpful in many aspects including epidemiological studies and policy decisions.

Methods

In this project, we have performed a compartmental district-wise analysis of spread of COVID-19 infections in the state of Karnataka, using the SEIRV model and regression techniques. We use the data of infections, population, vaccinations and serosurveys, starting from 11th October 2020, to calibrate our model. We make different assumptions about factors like mobility of people between the districts (the mobility matrix), efficiency of the available vaccines, etc., and study the results. The parameters which we are optimising for, are the contact rates of different districts during different phases of the pandemic. A more detailed description of our approach is as follows:

1. We start with the data from 11th October 2020 to 31st October 2020 (during the peak of the first wave of COVID-19 infections in Karnataka). We start the simulator with susceptible, infected and recovered fractions matched to the round-1 seroprevalance data projected to 11th October 2020. We tune the contact rate parameters during this period to match the number of reported cases on 1st November 2020 to within 10%. In this subtask, we assume that there is no movement of people in between the districts, hence we use the identity matrix as the mobility matrix during this period, so the COVID-19 disease evolves independently in each district. Also, we are using the absolute difference between the predicted cases and actual cases as the loss function for this subtask.

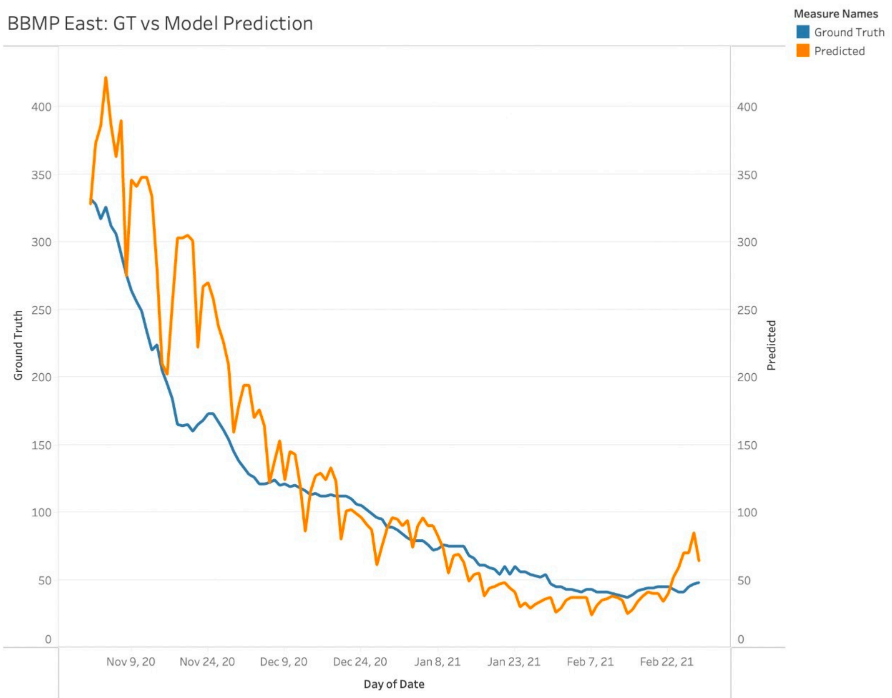
2. We consider the data from 1st November 2020 to 28th February 2021 (after the peak of first wave and before the onset of the second wave of infections) for tuning the district-wise contact rate parameters in the second subtask. We also use the antibody waning parameter to try and bring down the per day squared error for each district, and match the serosurvey data. We stick with the assumption that there is no mobility of people between different districts for this subtask as well.

3. For third phase, we consider the data from 1st March 2020 to 15th March 2021 and tried to predict data for 16th March. We implemented gradient-perturbation on beta for each district, along with vaccinations and immunity-waning. We were unable to get losses within 10%.

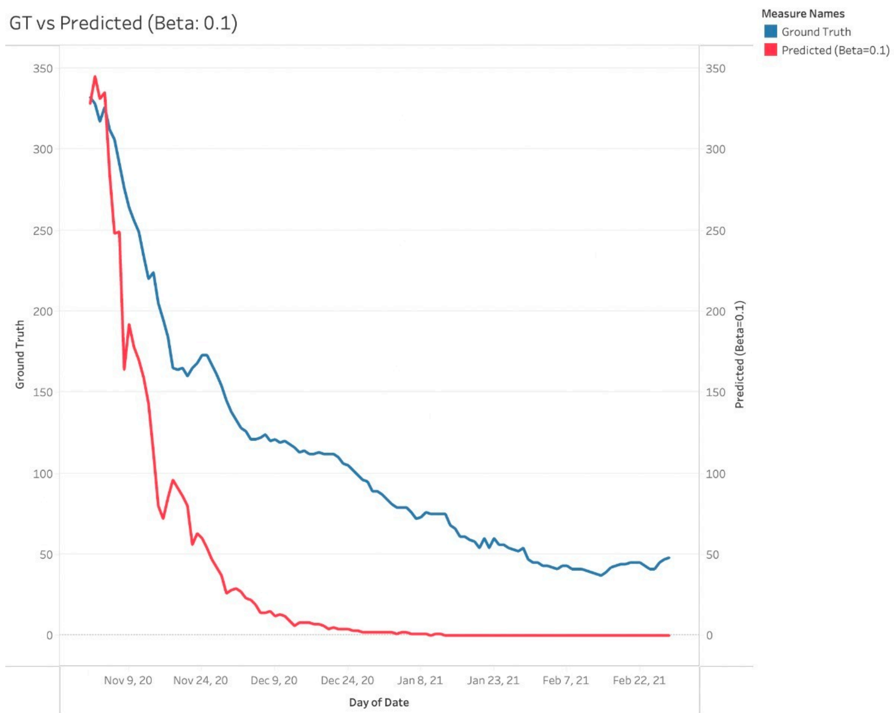
Results

In the first and second subtasks of our project, we have maintained our assumption that there is no movement of people between different districts of Karnataka, while estimating the contact rate parameters.

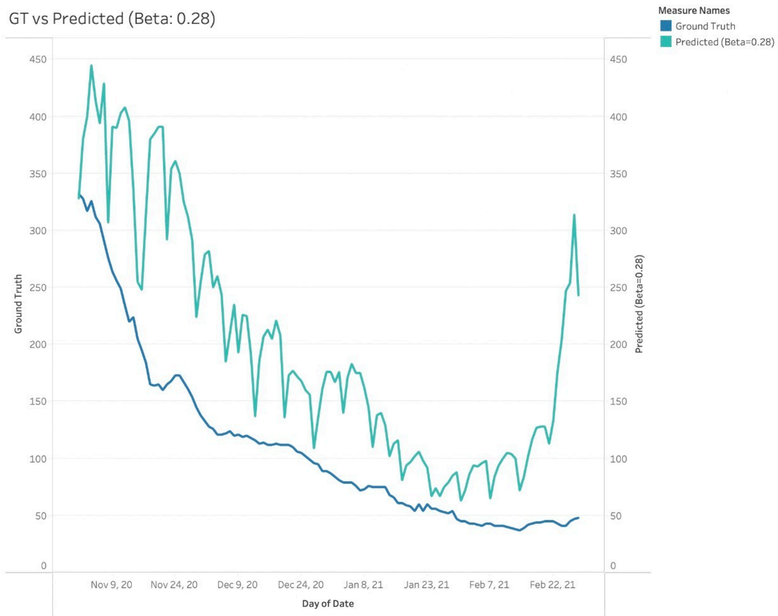
Sample plot for the timeseries of BBMP East area, predicted by the model (beta = 0.24), compared to ground truth, is as follows:



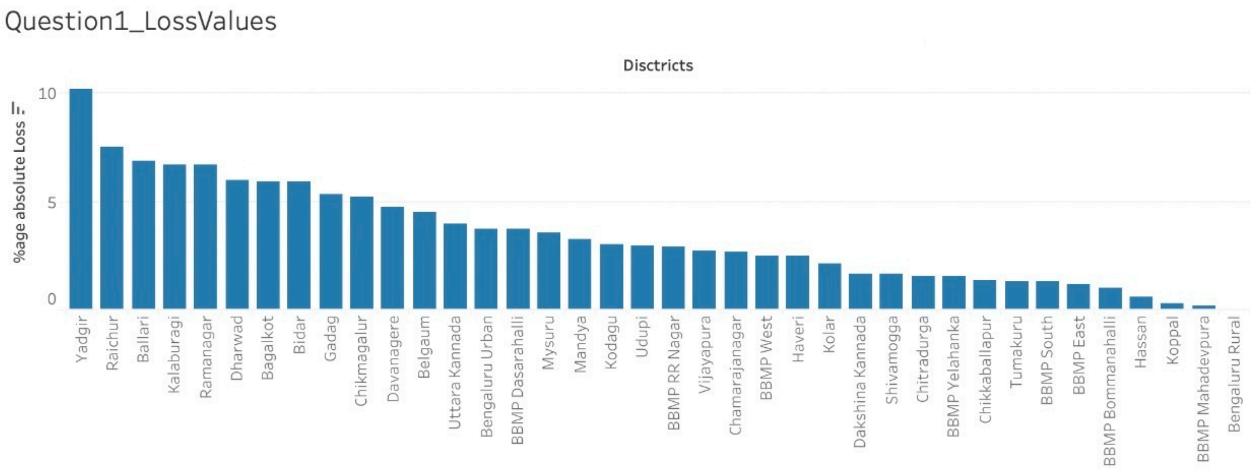
Hypothetical model for BBMP East if beta was 0.1 (if lockdowns are enforced strictly and efficiently):

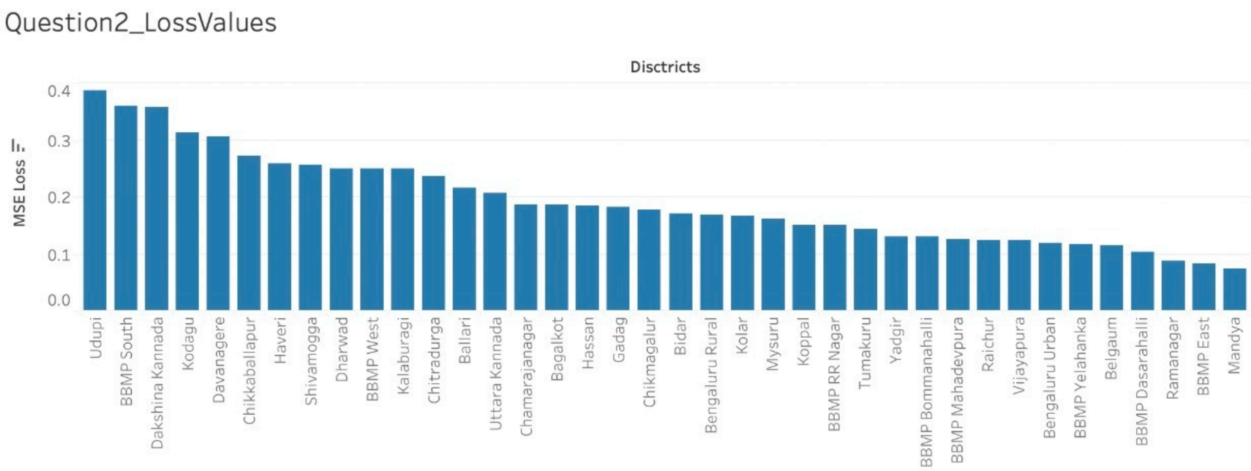


Hypothetical model of BBMP East if beta was 0.28 (if new variants come up which are more infectious / easily transmissible):

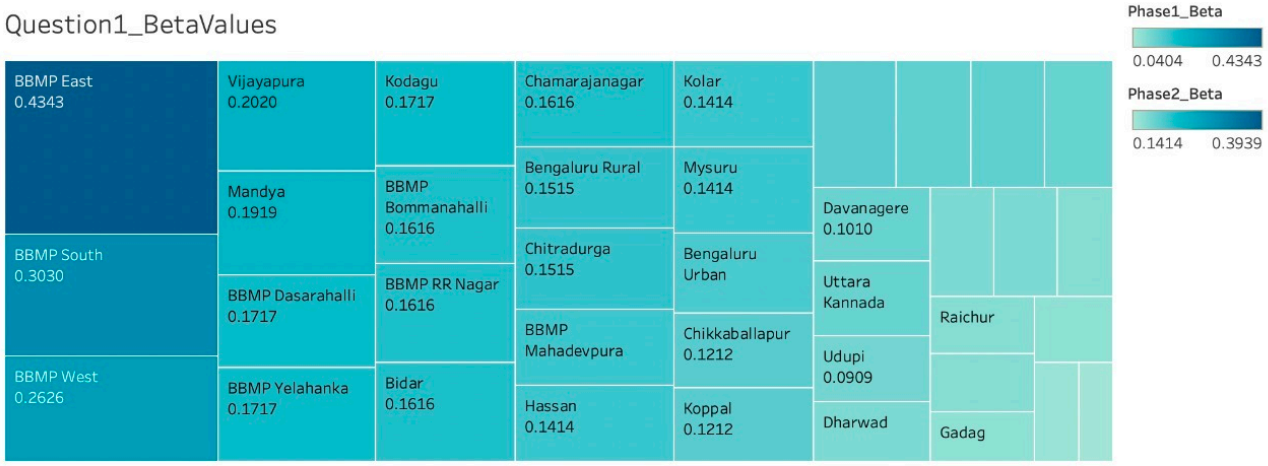


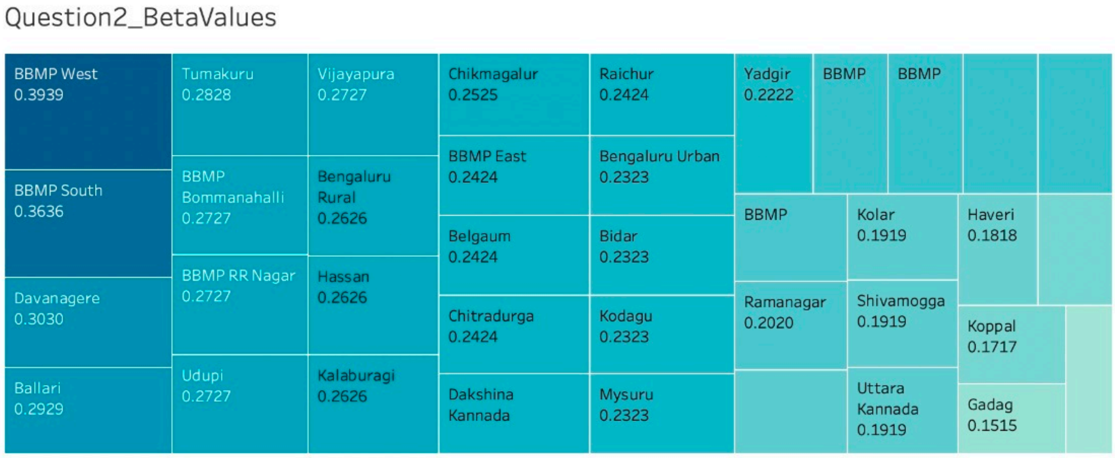
Comparison of losses at different districts for the first two subtasks, are as follows:





The corresponding estimated contact rates (beta values) for the first two phases of the pandemic are as follows:





For complete results including beta values and losses of all districts, please [click here](#).

Some notable observations from the above plots are as follows:

- Most of the districts having the highest beta values, in both phases, are BBMP areas. This observation can be explained by the high population density in the urban BBMP areas, making it easier for infected people to transmit COVID to others. Thus, the rate of slowdown of the pandemic (during both phase-1 and phase-2) was slower in urban areas (near Bangalore) as compared to rural Karnataka

- It can also be observed, that for most districts, the contact rate values are higher during the second phase as compared to the first phase. This can be explained by the fact that the first phase was right after the peak of the first wave, and cases were declining down more rapidly due to stricter lockdown enforcements at that time.

  As the second phase started and cases started reducing in numbers, lockdown restrictions were also gradually eased and the general public also took precautionary measures less seriously (like wearing masks, sanitizing, etc.), leading to slower reduction in the infection numbers in the second phase, hence the noticeably higher beta values.

- There are a few districts which had a higher contact rate in the first phase and lower contact rates in the second phase. There can be many reasons for this – one of them can be the actual effectiveness of the lockdowns enforced in those areas / districts. But we lack the local data of lockdowns from these areas to verify these claims.

- Vaccinations also slowly began in India during the second phase. But they seem to have not played a major role in reducing the number of vaccinations in second phase, because the absolute number of administered vaccines was quite less initially and the vaccines require some time as well, for the immunity to kick in.

- There are some districts like Vijayapura, Bidar, etc which have noticeably higher contact rates than say, central Karnataka during both phases. This can be explained by the proximity of these districts to Maharashtra, which was the worst affected state in India in terms of infection numbers, at that point of time.

Conclusion

We can conclude the following observations from our experiments with the first two phases of the pandemic:

1. Population density (e.g., large cities) matters a lot in modelling pandemics, and play an important role in determining the contact rates.

2. Lockdown can be effective for slowing down pandemics by reducing down contact rates, but only if enforced effectively.

3. Vaccinations are crucial in building immunity, but it takes some time for vaccines to build immunity.

4. Districts which border nearby states are also impacted by those states in reality, even if we hypothetically make the assumption of zero mobility across states and districts.

5. New variants which are more transm1issible pose a serious threat to the effectiveness of vaccinations and lockdowns.