White paper

Pandemic projections SEIQR model

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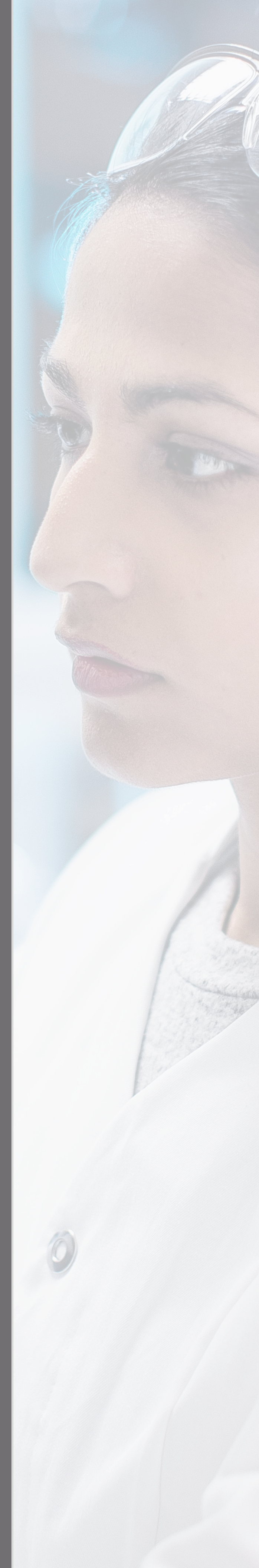


Introduction

The novel coronavirus **(COVID-19) has already infected close to 21.6 million* people across the globe** and has posed an enormous challenge, impacting economies, institutions, businesses and personal lifestyles.

COVID-19 hit India
in March'20 and as per the latest update,

India has recorded over

2.65M* cases with more than

51K* people succumbing to the disease.

Government intervention at an early stage included a complete lock-down, contact tracing and implementation of strict social distancing measures. While the rate of increase in the number of active cases was somewhat curtailed, cases still continue to rise at an alarming rate. The infected population trajectory for India may have shown positive signs of slowing down, however the disease continues to wreak havoc, prompting radical measures from the government and citizens alike.

As compared to the previous outbreaks of Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS), this novel coronavirus displays unusual epidemiological traits. Recent reports show that a large number of transmissions occurred through human-to-human contact with asymptomatic individuals. The estimated basic reproduction number (R_0) of COVID-19 is also comparable, if not higher, to that of SARS and MERS. It seems unlikely at this point that a vaccine would be available anytime soon, hence controlling this transmission may play a vital and vastly underestimated role in curtailing this pandemic.

In these turbulent times, statistical models have taken center stage in making key policy discussions and control strategies, largely due to the unprecedented nature of the situation and the many uncertainties about this infectious disease. While the authorities are grappling with this issue, the spotlight is on how to move forward. The model proposed in this white paper aims to help with making these informed decisions.

This is a novel 'Susceptible - Exposed - Infectious - Quarantined - Recovered (SEIQR)' model that derives its reference from the classic deterministic 'Susceptible - Exposed - Infectious - Recovered (SEIR)' compartmental model, and has been specifically designed to simulate propagation and spread of the COVID-19 pandemic in India.

The SEIQR model factors-in active learning of assumed parameters to incorporate impact of policy interventions (like lock-down) and provides a realistic forecast. While this model can be used to forecast the lifecycle of any pandemic, this whitepaper is focused on modeling the COVID-19 spread and recovery.

* Data as of August 17, 2020

Covid-19 prediction challenges

The most challenging question on everyone's mind is:

When can we get back to a "new normal" in this post-novel coronavirus world and open up the economy in a full-fledged manner?

Accurately predicting when India will be at the peak of COVID-19 infections through different statistical models has been a key focus area for governments and private sector organizations. An understanding of the timelines and local capabilities required to address the situation would have greatly helped in creating strategies to better deal with the on-going crisis and making decisions around mitigation and reopening.

However, COVID-19 doesn't affect each person and population in the same way, posing many challenges for data models. Moreover, policies are changing every week. Prediction from a model is as good as the ability to measure and adapt to the policy shifts at different levels of effectiveness.

Existing model approach and challenges

A curve fitting model, like the model made by the Institute for Health Metrics and Evaluation (IHME), looks at how the disease progressed in other geographies, like China, Italy and Spain, and tries to extrapolate a prediction from there.

> **The model tries to approximate the disease's progression in the U.S. by fitting a best fit growth curve, based on how the disease progressed in those other geographies that are further along with their COVID-19 infections.**

While this helps in providing us with a ballpark prediction, the model would not be able to account for differences in how COVID-19 might spread in other geographies, for how long individuals might be infectious, changes in treatment patterns, and most importantly, changes to public policy that alter the trajectory of the disease spread. That is because this approach is not modeling the disease dynamics itself, as reflected in the huge fluctuations in IHME's projections and the inability to explain this variability.

Why is local modeling so important?

Health care in this nation is practiced locally. For better or for worse, this decentralized approach to health care and public health policies means that different regions in the country have varying abilities to react and deal with the pandemic.

Furthermore, local modeling will help assess when it's safe and appropriate to reopen a local geography's economy, as well as prevent that area's health care system from being overburdened.

The data from Wuhan, China or Seoul, South Korea will not provide an accurate prediction of when New Delhi or Mumbai will reach its peak number of cases. India needs a model that can project deep into lower level geographies in a statistically robust manner. This is where the SEIQR model can make a difference.

SEIQR model

What is SEIQR?

The novel SEIQR model is a derivation from the ‘Susceptible - Exposed - Infectious - Recovered (SEIR)’ or ‘Susceptible - Infected - Recovered (SIR)’ compartmental models that are used to simulate the spread of diseases. SEIQR addresses numerous challenges that the other models typically cannot manage.

> **This sophisticated model was developed by adding a new compartment for quarantine and also segregating the exposed population into two categories (namely essential services and normal population).**

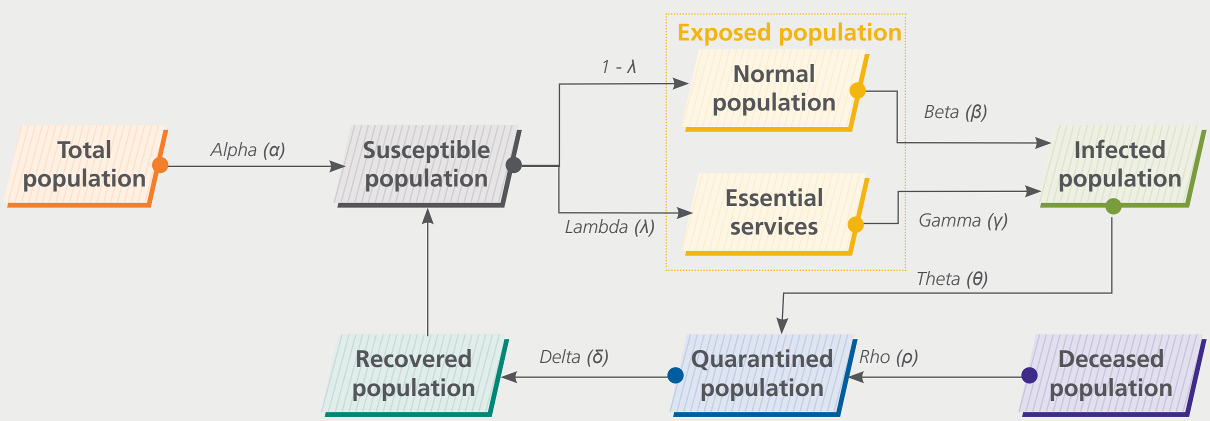
This differential is very important to the overall compartments as the rate of contact for the essential population gamma *(γ)* is almost three times the contact rate for the normal population beta *(β)*. More details about this are covered in the next section.

The SEIQR model is relevant because the current models do not have a dedicated compartment for the quarantine (Q) population from the actual infected (I) population This is important as COVID-19 is a disease like none other and has symptomatic and asymptomatic population, both with different dynamics and impact on pandemic projection.

Method

The model is basically distributed into seven compartments/variables that represent the various states of a pandemic like COVID-19:

1. The susceptible population S(t) at a given time t (the percentage of population that is at risk of getting infected from the virus)
2. Normal population P(t) at time t (the percentage of susceptible population that is classified as non-essential and consists of the general population, abiding the lock-down policies. Thus, they have a lower contact rate as compared to the essential services population)
3. Essential services population E(t) at time t (the percentage of susceptible population that is classified as essential services such as healthcare professionals, police and other front-line services. Thus, they have a higher contact rate)
4. Infectious population I(t) at time t (this denotes the population that is either asymptomatic or symptomatic)
5. Quarantined population Q(t) at time t (the population that has been identified as infected and has been quarantined)
6. The population R(t) at time t (the population that has recovered from COVID-19)
7. Deceased population D(t) at time t (the population that is deceased because of COVID-19)



The dynamics of these seven compartments are described by the below equations:

$$\frac{dS(\tau)}{d\tau} = -[(1-\lambda) * \beta + \lambda * \gamma] * I_\tau * \frac{S_\tau}{\alpha * N}$$

$$\frac{dI(\tau)}{d\tau} = [\{(1-\lambda) * \beta + \lambda * \gamma\} * I_\tau * \frac{S_\tau}{\alpha * N}] - \varphi * I_\tau$$

$$\frac{dQ(\tau)}{d\tau} = \varphi * I_\tau - \delta * Q_\tau - \rho * Q_\tau$$

$$\frac{dR(\tau)}{d\tau} = \delta * Q_\tau$$

$$\frac{dD(\tau)}{d\tau} = \rho * Q_\tau$$

Parameter estimations*

The novelty of this model is in the calculation of parameters and then using that value for the simulation of each compartment. For parameter estimation, a sophisticated technique is being used - that of learning from the data for the period starting from April 1, 2020 till date. Instead of taking a moving average of these values to get a single value for each of the parameters, these values are predicted on a daily bases and used to run the simulation to keep the model dynamic (and not run on constant parameter values). This facilitates learning from the fluctuations arising on a daily basis and predicting more accurately.

α Fraction of the total population that is susceptible. Current constant value is **1.5%** because of the government-imposed lock-down.

λ Fraction of the susceptible population that includes essential workers. Current constant value split is at **30%.**

β Contact rate (normal population). Value range is from **0 to 0.619.**

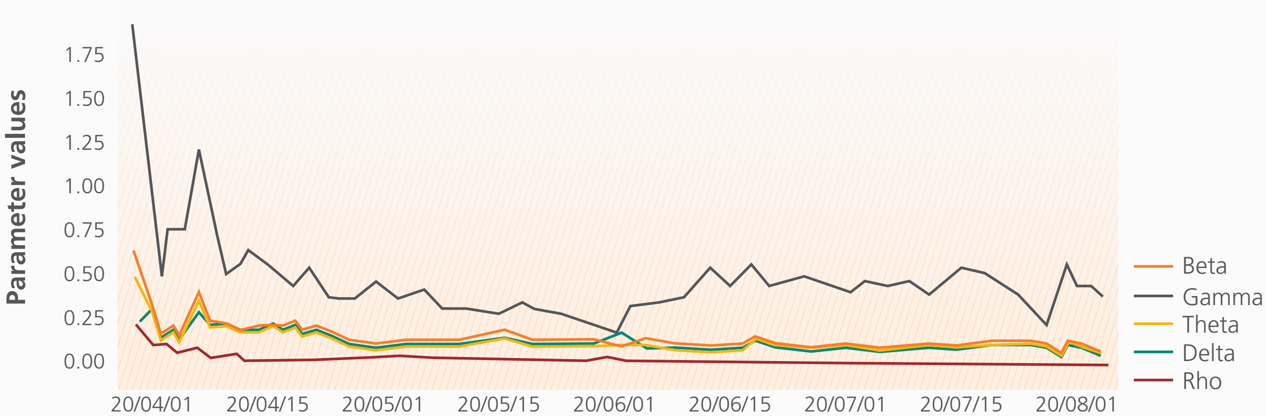
γ Contact rate (essential services population). Value range is from **0 to 1.856.**

θ Rate of daily infectious population getting quarantined. Value range is from **0 to 0.487.**

δ Rate of daily quarantined population getting cured (after 15 days). Value range **is from 0 to 0.4.**

ρ Rate of daily quarantined population getting deceased (after 15 days). Value range **is from 0 to 0.184.**

Parameters with time for India



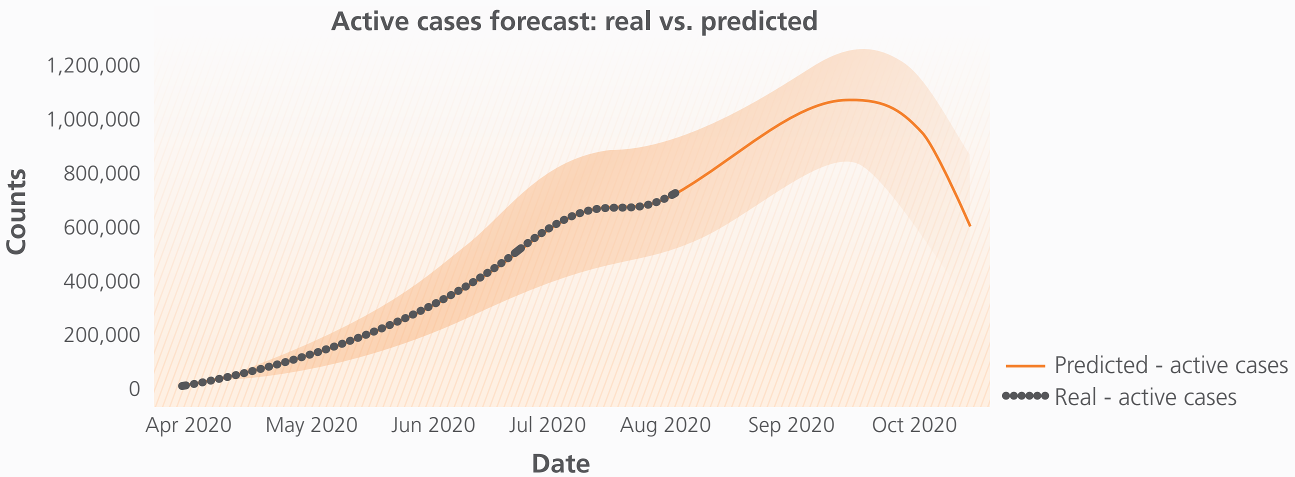
* Data as of August 1, 2020

Trend curves

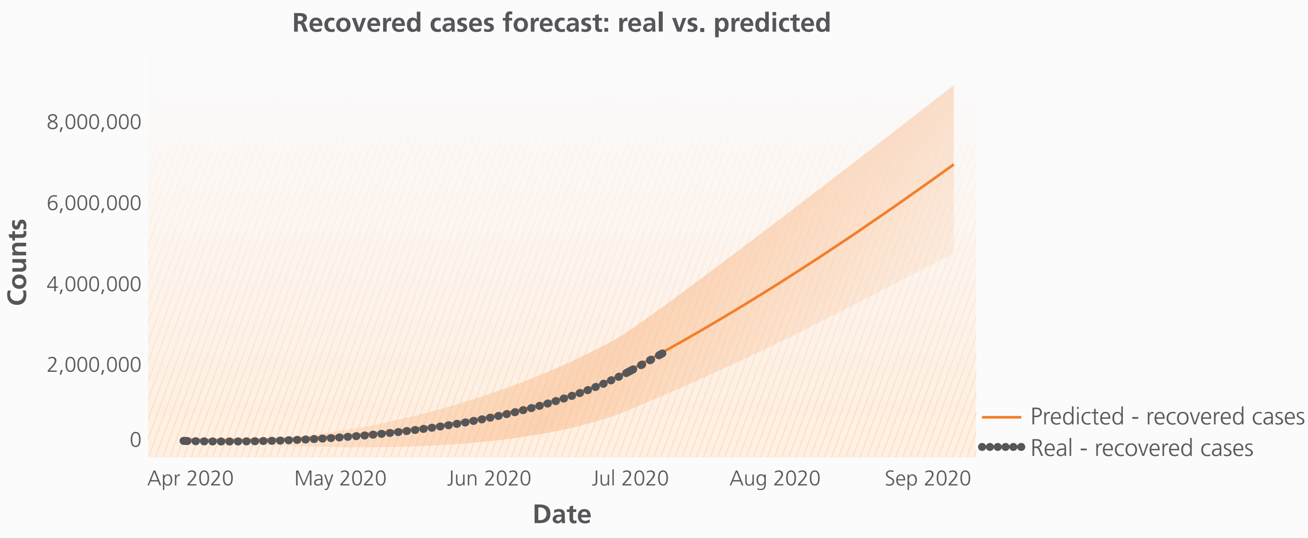
The prediction includes the total count of active, recovered and deceased cases for the entire life cycle of COVID-19 pandemic in India, assuming that the nation-wide lock-down is lifted in a phased manner from June 1 onward and the pandemic is expected to remain until approximately the first week of January 2021.

A quick brief about terminologies:

- **Active cases** correspond to the number of cases that have been reported in the country on any given date [mean absolute deviation (MAD) ~4.42%]

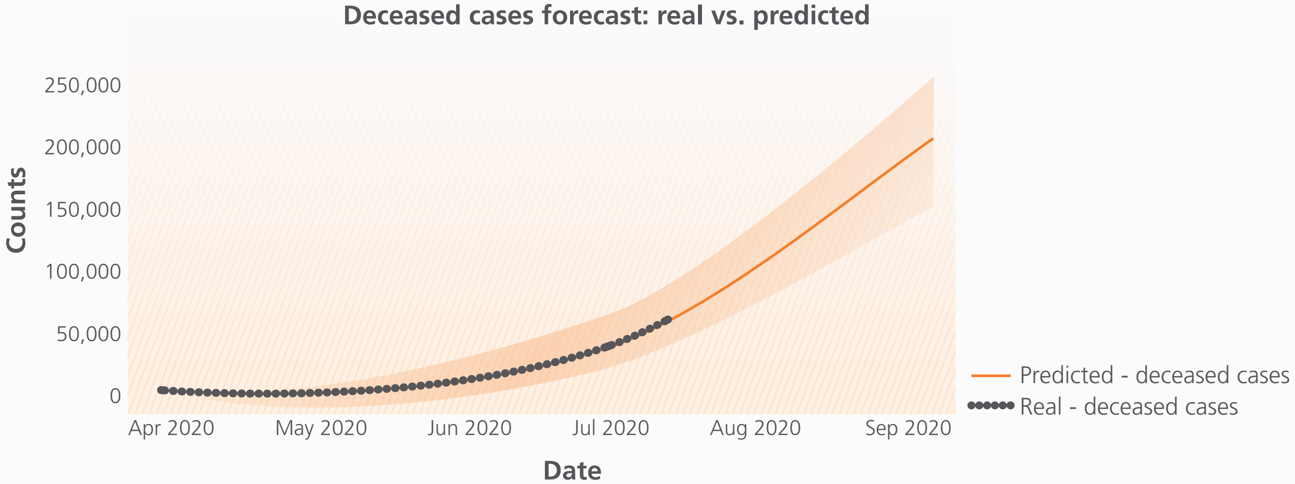


- **Recovered cases** represent the number of people who have been successfully treated and declared free of the virus in the country up till any given date [mean absolute deviation (MAD) ~5.01%]



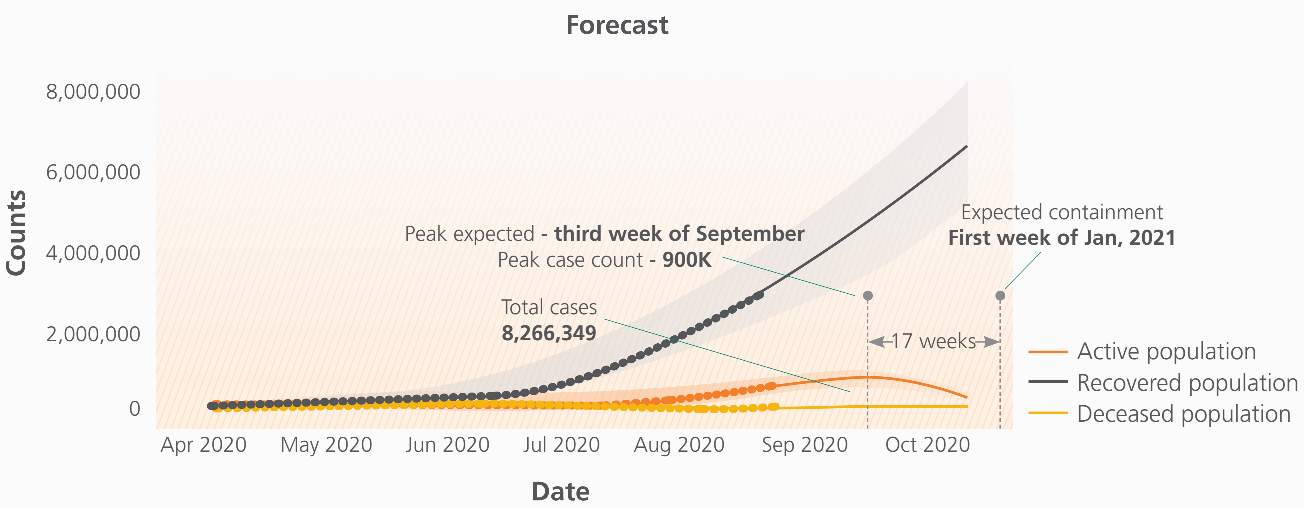
* Data as of August 17, 2020

- **Deceased cases** represents the number of people reported to have succumbed to the virus in the country up till any given date [mean absolute deviation (MAD) ~4.77%]



- Post this analysis, all of the above was plotted on the same axis to paint a comparative picture of the lifecycle of COVID-19 in India.

  Below are a few key observations:
  - **Peak date and case count:** active case count peak is expected to be around last week of September, achieving a case count of 900K
  - **Downward trend:** active case count starts declining post peak to negligible levels by the first week of January 2021
  - **Recovered and deceased cases:** numbers of recovered and deceased cases show an increasing trend with deceased cases getting stabilized earlier in the first week of October, while recovered cases plateau only in January 2021



* Data as on August 17, 2020

Scenario analysis

Scenario modeling was conducted to estimate the count of active, recovered and deceased cases with different timings of lifting the lockdown and opening up the country to assist with informed decision-making.

01 Nation-wide lock down not lifted for entire COVID-19 life cycle

As per the model's projections, for a scenario where the lock-down would have continued for the entire life cycle of COVID-19 in India (estimated around 200 days (third week of October)), the trends analysis would be as follows:

Peak date and case count

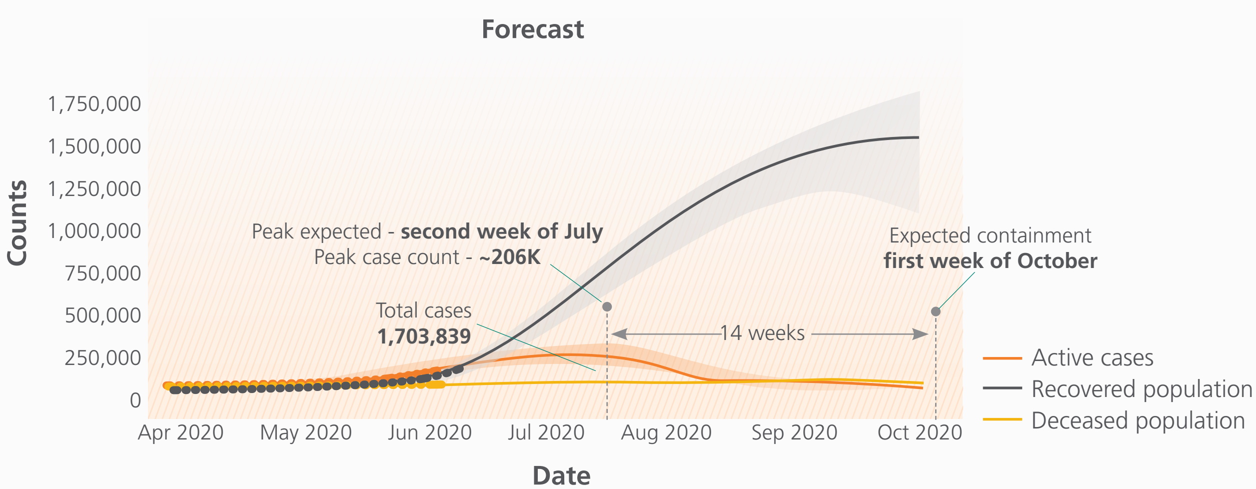
Active case count peak is expected to be around **second week of July,** achieving a case count of **206K**

Downward trend

Active case count starts declining post peak to negligible levels by **first week of October**

Recovered and deceased cases

Numbers of recovered and deceased cases show an increasing trend till **third week of October** although the rate of increase shows positive signs of slowing down



* Data as on May 31, 2020

02 Nation-wide lock-down lifted on May 3, 2020 and country in unlock mode

As per the model's projections, had the lock-down been lifted on May 3, it would have triggered a projected increase in the total active case count by **+100.08%**. Total infected population (area under curve) is projected to be **16.6 million**.

Below are a few key observations:

Peak date and case count

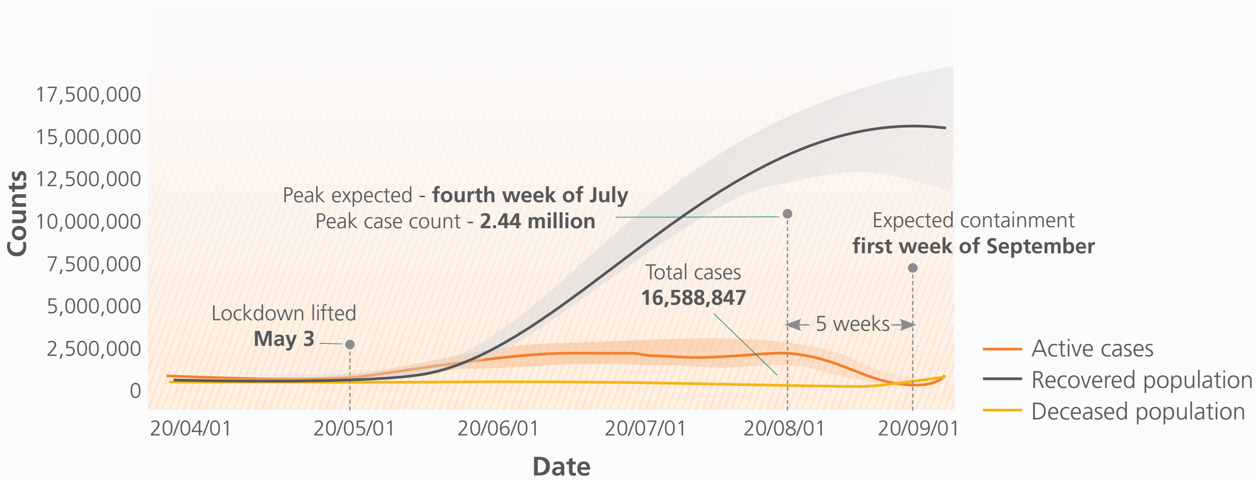
Active case count peak is expected to be around last **week of July**, achieving a case count of ~2.44M

Downward trend

Active case count starts declining post peak to negligible levels **after last week of August**

Recovered and deceased cases

Numbers of recovered and deceased cases show an increasing trend till **last week of September** although the rate of increase shows positive signs of slowing down



* Data as on May 3, 2020

Conclusion

COVID-19 will run its course and the effects will be staggering. Moreover, it is likely that India will have to face the secondary waves that Singapore and Japan are currently encountering.

To that end, the SEIQR model can help improve the response to future waves of COVID-19 in India, by incorporating more data sources. Having a well-engineered software solution that can automatically return daily projections as soon as the earliest warning signs appear can save lives while also benefiting economies. The SEIQR model can better identify people that are unable to access routine care and are now most in need of additional help. Accordingly, help can be extended to those people, helping them fill the gaps in their care so they can avoid the emergency room or hospital for critical care.

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