**Expecting the unexpected: Stochastic modelling of COVID-19**

16th September 2020

**Kees van Heugten, Rob Smit and Servaas Houben show the benefits of a stochastic model for COVID-19 infections in the Netherlands**



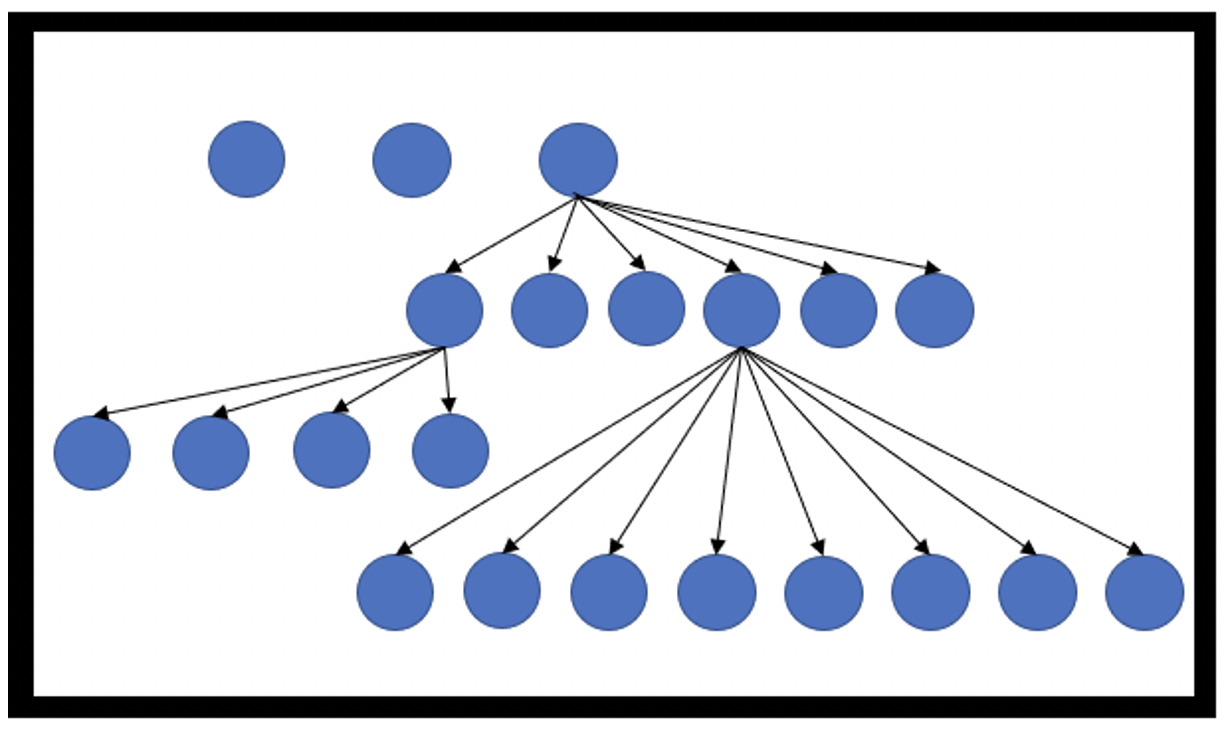
Due to the current COVID-19 pandemic, there are several models that describe the behaviour of viruses. Studying the models that are publicly available, we concluded that these tend to be deterministic, projecting only the most likely outcomes in terms of the number of people who will suffer from the virus. Governments introduced measures in response to COVID-19 because severely ill people need medical or intensive care. The corona-dashboards generally used give information about relevant metrics, such as the number of infected in the country, the reproduction factor and the number of people who are hospitalised or need to go into intensive care, but not confidence intervals around these; we propose such a model.

**The status of an individual in the population**

In general, the virus models use more or less the same statuses that an individual can have in relation to the virus. An individual can be healthy (never infected), be infected, become sick due to the virus, recover from sickness (and possibly be immune for a certain period), become healthy again or die due to the sickness.

**The asymmetrical behaviour of COVID-19**

The COVID-19 virus behaves asymmetrically: there are infected individuals who do not infect others, as well as individuals who infect a lot of people (see Figure 1). Due to this behaviour we see local outbreaks of the virus and ‘super-spread events’.

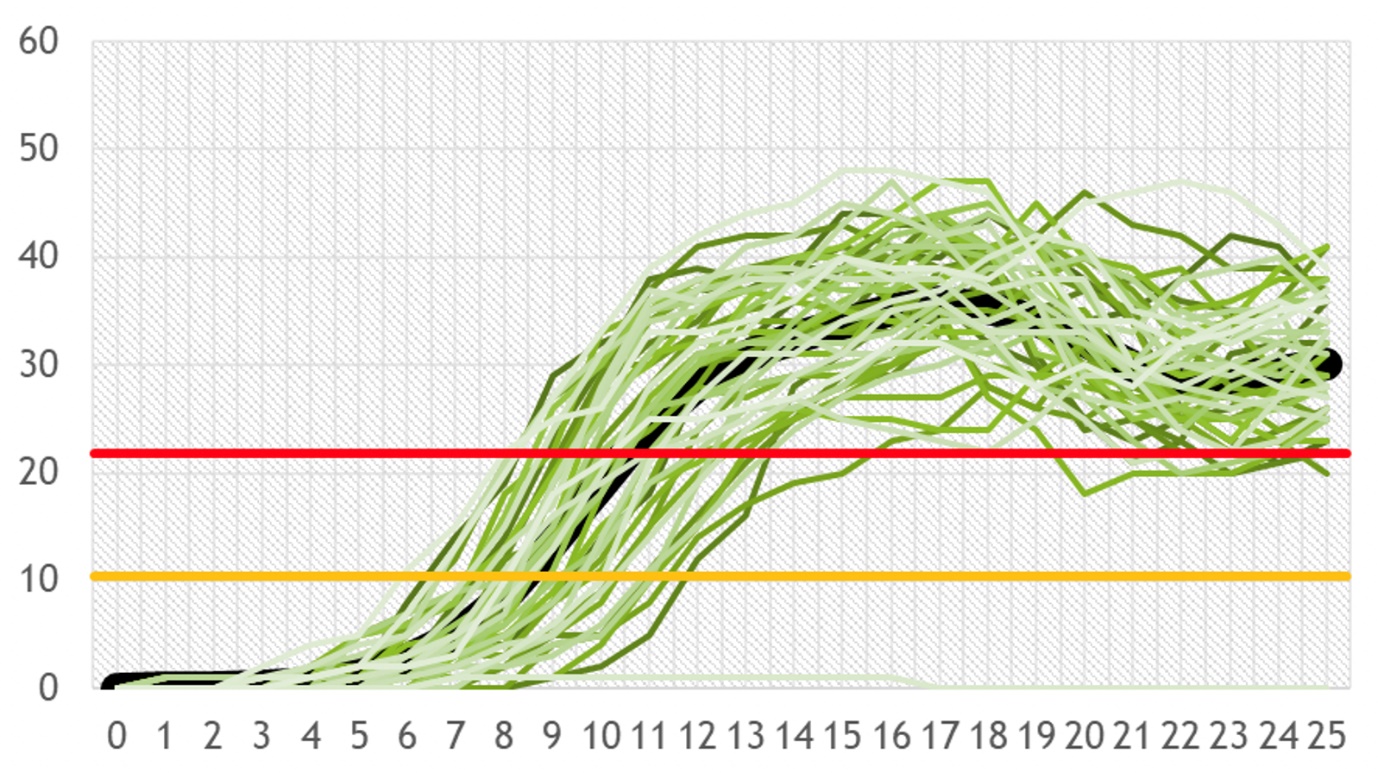
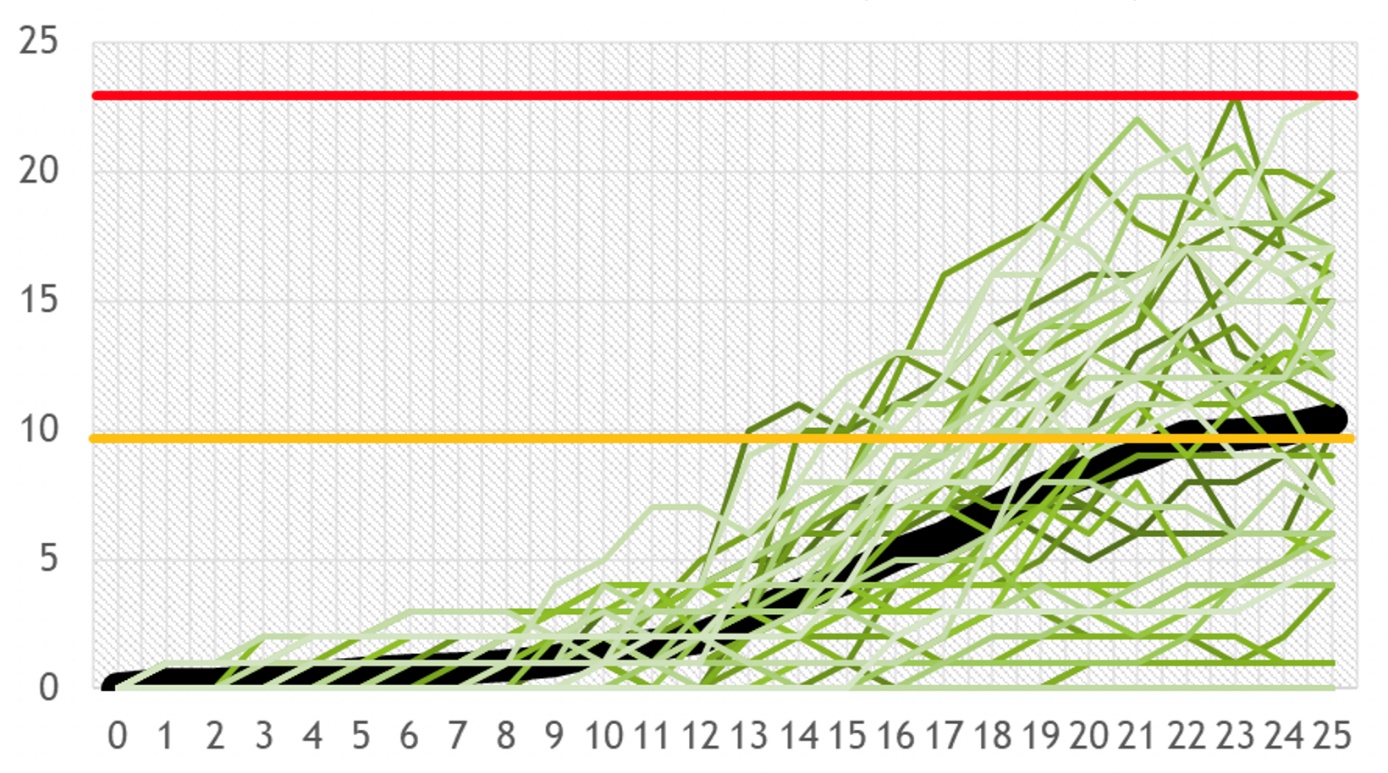
*Figure 1: Asymmetrical infection process with reproduction factor 2. From the first three infected only one infects six others, while the other two don’t infect. In the second period only two infect, while the other four don’t. From the two that infect, the first infects four others and the second infects eight others.*

Deterministic models that work with a population reproduction factor do not take this behaviour into account, which can result in an underestimation of the expected capacity for hospitals and intensive care units (ICUs). In our COVID-19 model we therefore introduce individual reproduction factors that are assumed to draw from a skewed probability distribution. To get the required skewness we use the discrete gamma distribution.

**Simulations using the asymmetrical behaviour of COVID-19**

Based on the age distribution of the Dutch population, and taking into account the assumptions regarding the levels of sickness (asymptomatic, medium symptomatic sick and severely sick) and corresponding assumptions regarding the duration of immunity, we simulated the stochastic behaviour of COVID-19.

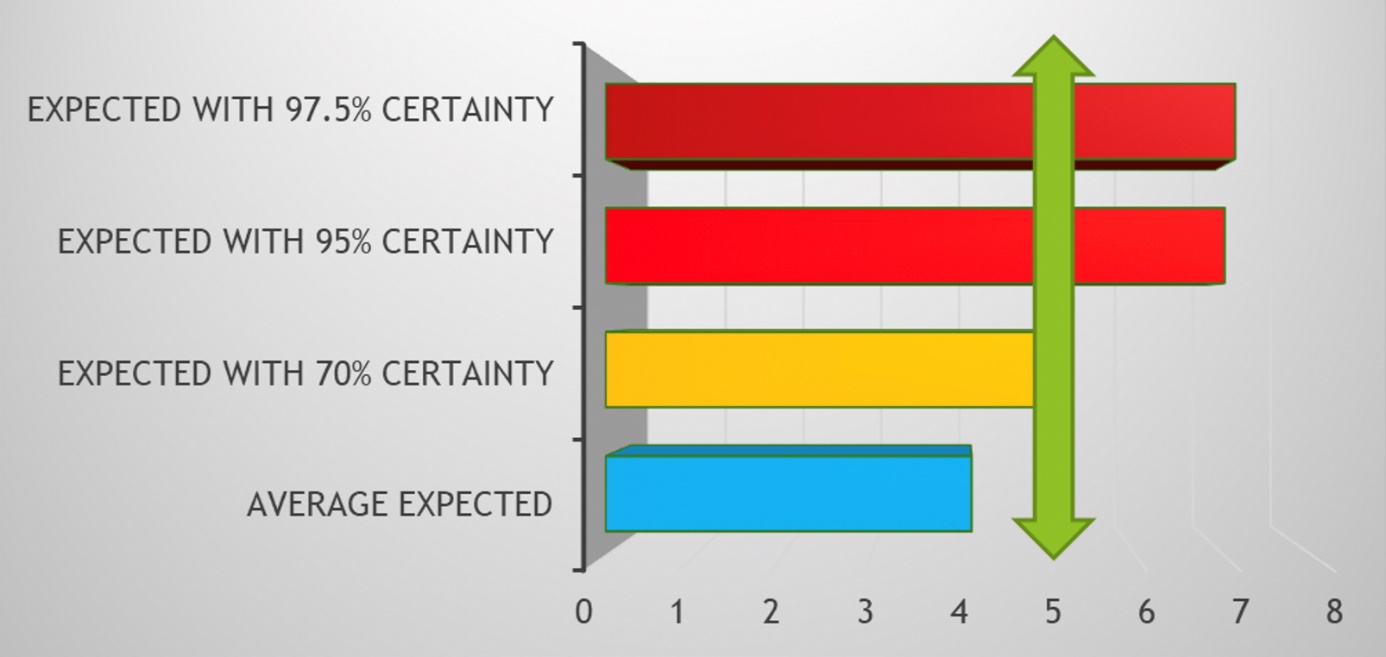
*Figure 2* illustrates the number of severely sick individuals per 10,000 inhabitants. It is assumed that there are 10 hospital and ICU beds available per 10,000 inhabitants (yellow line) and the maximum hospital capacity is 23 (red line). Without taking measures, we observe that the average number of beds will be 40 in 10,000, so the capacity of beds will be too limited. Therefore, measures need to be taken to ‘flatten the curve’ in order to avoid capacity problems.

*Figure 2: The number of severely sick people, without intervention.**Figure 3: The number of severely sick people, with intervention.*

*Figure 3* illustrates the number of severely sick individuals per 10,000 inhabitants, assuming that measures are taken. When the number of severely sick individuals is above two per 10.000 or the number of infected individuals is more that 1% of the population, measures are introduced to reduce the reproduction factor to 1. As a result, we can see that, on average, the number of severely sick individuals has a maximum value of 10 per 10,000, which matches the capacity of available beds. Looking at the 50 scenarios that are simulated, we see that planning based on the average number can still result in capacity problems in relation to the number of available beds: there are scenarios that require almost 50% extra capacity than expected.

**Introducing a stochastic dashboard**

The current dashboards used by governments do not take into account the stochastic nature of the COVID-19 virus, which can lead to an underestimation of the capacity needed. We therefore propose a corona-dashboard that takes the stochastic nature of COVID-19 into account (*Figure 4*).

*Figure 4: COVID-19 Barometer for hospital and ICU capacity in the Netherlands.*

This dashboard shows the average capacity needed within four weeks from the current date (predicting the capacity at September 28, 2020), based on the number of infections and the current reproduction factor, and taking into account the local outbreak character of the virus and the skewness of infections. The hospital and ICU capacity is represented by the green vertical line of five beds per 10.000 (50% of the capacity shown in Figure 2 and Figure 3). The dashboard not only shows the average number of beds per 10,000 inhabitants, but also the confidence level of the number of beds once more or less beds are reserved to cover for COVID-19 patients. This dashboard gives policymakers extra information, in addition to the use of models that are only based on averages; they can use it to plan capacity, taking into account the confidence level they require – ie the level of risk they are willing to assume.

**Next steps**

To arrive at a more reliable corona-dashboard, the following questions need to be answered:

* Do asymptomatic sick individuals infect others? And if so, do they infect with a lower reproduction rate compared to the infected and symptomatic cases?
* What is the level of skewness of the COVID-19 infections? The confidence levels depend on the assumed level of skewness of the infections.
* What is the duration of immunity, and is this related to an individual’s level of sickness?

A corona-dashboard taking into account the confidence level is a useful tool for policymakers and will even be more useful when these questions are answered to give smaller and more precise intervals.

For further information and discussion, please visit [www.crownactuaries.eu](https://crownactuaries.eu/).

***Kees van Heugten****is a team leader at elipsLife.****Rob Smit****is a self-employed actuary.****Servaas Houben****is senior manager at EY.*