Predicting possible outcomes to coronavirus and other pandemics with models and simulations

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Lately, our daily lives include reading complex news items with analysis of curves, simulations and models of COVID-19. Municipal governments present predictions of possible outcomes from modelling, while provincial and national governments have press conferences discussing policies to respond to the potential spread of the disease.

But what does all this data mean? How are these predictions made? Who develops these models and simulations, and how are they applied?

Learning from observation

The models we read about are a representation of the world around us that we use to reason and learn.

But why do we need models? We could use real-world observations and experimentation instead. For instance, if we wanted to study the pattern of customers in a pharmacy during the current COVID-19 pandemic, we could observe shoppers and record their behaviour in a spreadsheet. We may find out that there are 30 customers per hour over lunchtime. At 7 p.m., 120 customers are served. By midnight, there's only one customer every 10 minutes to attend to.

Based on these observations, managers at the pharmacy could conduct different experiments to reduce delays. They could open up an additional cash register at the peak period or add a line for people paying by credit card. They could try to use a line for customers with five articles or less. The information collected from these experiments can help the managers at the pharmacy to make an informed decision.

Although experimenting with various methods produces more precise knowledge, there are other considerations such budgets, time, ethics, risk and system complexity.

Developing models

A model becomes handy when you want to add many complicated factors. A model is a representation of the physical world that we can manipulate and use to think about nature. It is often represented with mathematical equations. For example, if we observed that there are 20 percent more people infected by the coronavirus in a city per day, a very simple equation to model such behaviour would be:

$$n(tomorrow) = n(today) + (0.20 * n)$$

Here, *n(today)* represents the number of persons infected today. This is referred to as a *parameter* of the model, which we could use to predict how many people are going to be infected tomorrow, next week, next year and so on.

Mathematical models address the limitations of risk, ethics and cost. But sometimes they can be an over-simplification of the world.

Complex models

The more complex the model equations are, the more difficult it is to solve them. A model can consist of a combination of hundreds of equations like the one above and incorporate complex parameters such as infection rates, mobility of individuals, access to health facilities and the effects of the weather.

Simulation is a way of studying these complex models and can help predict specific cases of interest. For example, a simulation does not have all the answers, but it could help answer particular questions, such as: what will happen tomorrow for women above 65 years old who are in good health but have no access to clean water?

These days, simulations are executed using powerful computers with thousands of processors that can conduct very large numbers of complex experiments at reduced cost and with zero risk. They can be combined with advanced visualization tools to help with the decision process.

Informed decision-making

Conducting experiments, developing mathematical models and designing simulations help governments to make informed decisions. During the ongoing COVID-19 pandemic, there have been daily press briefings in which senior officials have discussed the results of models and simulations with the public.

For example, the news has covered studies on the prediction of health-care capacity in the United Kingdom based on advanced models and simulations. Many different models were used in the U.K., which prompted the government to change its initially relaxed policy to enforcing quarantine and social distancing.

A similar story can be seen in the management of the pandemic in the United States. Advanced models showed that if social distancing was not enforced, the country could be short almost 13,000 beds, including 8,000 ICU beds, and a projected death toll of over 200,000 people. These models influenced the government to put new isolation measures in place.

In Canada, Ontario's provincial government reviewed a summary of the models used to predict the effects of the pandemic in the province. The simulations showed the results of different public health measures and provided insight into how the government formulates policy.

The Canadian federal government examined modelling results for the whole country. The simulations revealed how policies for travel bans, self-isolation, school closures and social distancing measures slowed the spread of the virus. A recent briefing outlined different scenarios that have been simulated to forecast short- and long-term results of the pandemics.

Model limitations

But no model is perfect. Even the most complex models we use today, which include hundreds of different parameters, are simplifications of reality. The variations seen in predictions come from the complexity of the real world—there are too many variables to have a perfect model.

In the context of this coronavirus pandemic, there are many variables to consider: every person will react differently to the virus; air drafts could change the trajectory of the droplets after a cough or sneeze; some of those infected may die of natural causes. No model can include all details.

Modelling and simulation can provide insights when combined with advanced visualization tools and analytics, constant data collection, fine tuning and validation of the results. This helps governments to establish policy informed by scientific evidence and research. In the upcoming years, more research, simulations and modelling will support worldwide efforts to be better prepared and reduce the negative effects of social distancing.

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