The role of mathematical models in developing policies for controlling COVID-19 transmission

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As the coronavirus disease 2019 (COVID-19) pandemic has progressed, mathematical models have become increasingly familiar to the public. Two models described in the *MJA* have been adapted for use to help formulate and refine the Victorian roadmap that has allowed an easing of social restrictions while maintaining control of COVID-19 transmission.[1,2]

Models may have many uses, including understanding the main drivers of disease dynamics or in planning trials, but for public health policy they are particularly useful for assessing "what if" scenarios. Models are necessarily abstractions of the main processes that drive COVID-19 transmission and are not designed to capture the full complexity of human interactions. As often noted, "all models are wrong, but some are useful".[3]

For example, compartmental models are commonly used to predict the spread of many diseases.[4] The parameters that govern the flows of individuals between susceptible, infective, and recovered compartments can be estimated from empirical data. One key assumption is that any person has an equal chance of meeting any other member of the population ("homogenous mixing"). Although this might seem absurd, for some diseases this assumption does not significantly affect model outputs.[5] These simple models have been adapted to predict the course of COVID-19 without public health interventions[6] and to assess the effectiveness of current public health interventions and project the likely short term trajectory of the outbreak.[7]

As case numbers decline, chance plays an increasingly large role in determining the future course of the outbreak. This is particularly true for COVID-19 because of the heterogeneity of infectivity; 10–20% of infected people cause around 80% of infections.[8,9] This makes intuitive sense; whether an outbreak will proceed from a single infected individual depends on their characteristics and behaviour. Someone who lives alone and works from home is less likely to transmit disease than a worker in a high risk workplace and living in a crowded household.

The Burnet Institute Covasim model takes a different approach.[10] An agent-based model, it attempts to simulate interactions between individuals to estimate outcomes at the population level. Unlike compartmental models, they require the estimation of many parameters, including the number of contacts and the likelihood of transmission in different settings. While some estimates might be informed directly by empirical data, this is not possible for many (eg, the probability of transmission at a sporting event). The behaviour of the model can be "sense checked" against collected data, and the model can then be run several times to explore the range of possible future outcomes under different policy settings.

Because of this uncertainty, the outputs of these models should be regarded as indicative rather than as precise quantitation of risk. However, they can be helpful in defining the relative risk associated with various scenarios. For example, the Covasim model suggests that opening pubs and bars early would be risky, but this risk can be mitigated by high uptake of a contact tracing app, or by physical distancing.[10]

It should be emphasised that models are only one tool used for formulating policy. Many factors cannot be easily captured by models. For example, if pubs and bars are open, compliance with physical distancing and the uptake of a contact tracing app needs to be considered.

In formulating the Victorian COVID-19 roadmap, these models were used to estimate the influence of the extent and timing of increasing aggregate movement and interactions on the risk of losing control of transmission. As many potential restrictions could have been modelled, the Victorian government worked closely with the modelling groups to determine which policy settings were implementable and proportionate. However, the degree to which people report their contacts, the workplace and residential settings in which infections occur, and the involvement of marginalised communities are all also important when setting thresholds for re-opening businesses and venues.

Mathematical models provide simplified representations of reality in which different scenarios can be tested without experiencing them. In retrospect, the first model used predicted a slower fall in case numbers than was observed,[11] but later models more accurately predicted the dates on which targets were met.[12] This suggested that the updated model inputs were generally sound. However, models must be supported by a range of qualitative and quantitative assessments and tools to translate their projections into policy.

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