- Department of Health & Social Care (https://www.gov.uk/government/organisations/department-of-health-and-social-care)
- Scientific Advisory Group for Emergencies (https://www.gov.uk/government/organisations/scientific-advisory-group-for-emergencies)

Guidance

Introduction to epidemiological modelling, October 2021

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1. What is epidemiological modelling?

Infectious disease models are used to understand the spread of a disease through populations. We use these to investigate how the COVID-19 epidemic could unfold in the UK, and what the consequences could be for the UK's population and its public services. This includes projecting how fast a disease may spread; how many individuals may become infected and may require treatment; how many may die; and how these numbers may change over time.

Each infectious disease epidemic is very different - Ebola, HIV, Influenza and Polio have all behaved quite differently. They all, however, share the same basic underlying process of being spread from person to person and so can be modelled using the same broad frameworks.

These models have three types of inputs:

1. details of the UK population; for example the age distribution,
2. estimates of the key characteristics about the virus that is being modelled, the resulting disease, and people's behaviour; for example how quickly and easily a virus is transmitted from person to person, and
3. how the population's characteristics interact with the virus' characteristics.

The numerical inputs are known as the models' parameters. The models also have an underlying structure, which determines which parameters are included, for example, some models might not include the age of people in the population. The models can then be used to understand what happens over time as the virus is transmitted from person to person.

Models are, by their nature, a simplified representation of reality. Models cannot, and do not try to, account for every possible detail of changes in government policy, the nature of the virus and how the population is interacting. Instead, they try to capture the important aspects. They are often limited by the available data and the models' outputs are only as good as the quality of the data that goes into them.

There can be substantial uncertainty in the models' results because the future is, for the most part, highly uncertain. The models factor in what is known with reasonable certainty about the future, for example, the planned progress of vaccine rollouts. Many things are unknowable however, for example if a new variant will emerge and what characteristics it might have. The further into the future the models consider, the greater this uncertainty is as there will be more of these unknowable possibilities.

Each model output (or combination of model outputs) will have a measure of uncertainty associated with it to capture this. This uncertainty interval shows the range of values within which the observed outcomes are highly likely to lie. This does not mean that the actual outcomes data will not be outside the interval, just that it is less likely under those conditions.

Modelling can never exactly replicate reality and therefore no individual model will give a perfect description of the future. It is precisely because of this that we do not rely on just one model. We consider a wide range of views on the data and intelligence available from several independent groups, who use different approaches to produce a varying set of answers to each question the models are asked. A consensus position is agreed through a robust discussion comparing and challenging the different models' results. Where these independent approaches give similar answers, it gives greater confidence in those outputs; if they differ then understanding why can itself be very informative. This diversity of voices and peer challenge means we are confident that the resulting evidence is robust.

The government bases its decisions on a large and varied range of data and evidence, not only COVID-19 modelling. For example, this might include analysis on how full hospitals are and numbers of cases in various regions of the country, COVID-19 infection surveys from the Office for National Statistics (https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19infectionsurveypilot/previousReleases) and REal-time Assessment of Community Transmission (REACT) (https://www.imperial.ac.uk/medicine/research-and-impact/groups/react-study/real-time-assessment-of-community-transmission-findings/), or international comparisons. It will also include analysis and evidence on wider health, economic and societal impacts. Models, however, are able to provide quantitative evidence for the potential impact of different policies on the epidemic's future.

2. What is modelling used for?

Scientific Advisory Group for Emergencies (SAGE) provides expert scientific advice to the government on COVID-19. The government receives evidence on epidemiological modelling from the UK's world-leading infectious disease modelling groups. These groups work together as members of the Scientific Pandemic Influenza Group on Modelling (SPI-M-O) which is an operational sub-group of SAGE.

View the scientific evidence supporting the government response to COVID-19 (https://www.gov.uk/government/collections/scientific-evidence-supporting-the-government-response-to-coronavirus-covid-19)

As part of this evidence, individual modelling groups from SPI-M-O and other academic groups produce national and regional estimates of the reproduction number (R) and growth rate each week. These are statistically combined to produce the published consensus estimates of the R value and growth rate (https://www.gov.uk/guidance/the-r-value-and-growth-rate).

See further detail on how estimates of the R value and growth rate are produced. (https://www.gov.uk/government/publications/reproduction-number-r-and-growth-rate-methodology)

SPI-M-O also produces regular medium-term projections of hospital admissions and deaths. These are not forecasts or predictions. They represent the trajectory that the epidemic might follow, if the trends seen in the latest data available (at the time the projections were produced) continue. As such, the projections do not include the effects of any future policy or behavioural changes, but do include the planned progression of the vaccine rollout.

SPI-M-O additionally uses models to consider scenarios for what might or could happen in the future under a given set of circumstances, rather than giving a single specific forecast or prediction. These circumstances can be changed in the model inputs to explore what might happen in the future, for example, if policy interventions were made, or new treatments or vaccinations became available. These scenarios are extremely time- and resource-intensive to develop, run and assure.

The models help to visualise the potential range and scale of impact for measures such as hospital admissions and deaths, as well as the uncertainty around these, given the modelling inputs and assumptions. By choosing different combinations of model parameters and simulating the different trajectories, the resulting range of scenarios can support decision makers in choosing whether to take a particular course of action. It can also allow for a variety of comprehensive contingency plans to be made to deal with different eventualities.

These types of modelled scenarios are not predictions or forecasts. For example, models may use a given value of the R value (https://www.gov.uk/guidance/the-r-value-and-growth-rate) from a specific date and then run forward for a certain number of weeks to explore the potential impact on hospital admissions. This does not mean that this is the expected outcome for hospital admissions given current trends, but is an indication of what might happen if the R value changes in the specified way. These results can be used to support government decision making and planning.

Sometimes we ask modellers to produce ‘reasonable worst-case scenarios’. This is where the parameters of the models are chosen to generate a challenging, but plausible range of possibilities describing what might happen in a highly pessimistic scenario. For example, this could be a scenario of no further policy changes, with some assumptions made more pessimistic, such as the emergence of a hypothetical variant of a virus that evades immunity. These sorts of scenarios are designed to inform government planning for more extreme situations.

Scenarios are used to inform decision-making and our understanding of the epidemic and policy changes at the point at which they are made. The models used are fitted to the data available and able to recreate the past epidemic up to that point. Comparisons between modelled scenarios and what actually happens following a decision are less informative about the modelling itself than they are about the impacts of these changes and the important processes driving the epidemic. Ongoing monitoring of the epidemic over time, particularly following policy or behavioural changes, provides new information on these aspects, allowing groups to refine their assumptions and models.