COVID-19 MODELLING: BRIEFING NOTE #1

DATE: 31 MARCH 2020

Introduction

The Department of Health (DoH) has established a Covid-19 modelling group, chaired by the Chief Scientific Advisor. Membership of the group is included at **Annex A**.

The group will consider outputs from a range of sources to inform its judgement on the projected course of the Covid-19 epidemic and its impact. The information sources used include:

- A SAGE paper on Reasonable Worst-Case Planning Scenario (29/3/20) and including the projected impact for the UK on key measures, scaled to the Northern Ireland population.
- A NHS England/Improvement tool ('CovidUsageR') developed by Jonathan Pearson (Versions 2.3 and 2.4). This tool relies on a two-step process: it does not generate its own epidemic curves, but instead takes its outbreak data from the outputs of the Imperial College / Ferguson *et al.* agent-based model; it then applies assumptions based on those advised by SAGE about the probability and duration of key events, such as ventilation.
- A Susceptible-Infectious-Recovered (SIR) differential equation compartment model developed by Paul McWilliams, Strategic Investment Board.
- A System Dynamics model developed by Simon Dodds (SaaSoft) a healthcare systems engineer. The group has access to outputs of this model only, not the model itself.
- The Republic of Ireland Model - outputs not yet available.

Terms of Reference

The Terms of Reference for the group are:

- To provide 'reasonable worst case' estimates of the potential course of the epidemic which will be used to inform surge planning, public health policy and risk management decisions in Northern Ireland.
- To collaborate with ROI colleagues to model the epidemic on an all-Island basis.

Reporting

The modelling group will report to the Chief Medical Officer and will consider information from range of sources to inform its judgement on the potential course of the epidemic. During the changing situation, updates to models and their validation will be considered in the round to inform the judgement of the group.

The models will be adapted over time as more data becomes available and this briefing note will therefore be updated at least on a weekly basis.

The group will consider three scenarios: a reasonable best case scenario, a reasonable worst case scenario and a worst case scenario. The outputs reported in this briefing note for each of these scenarios include:

- The peak number of Covid-19 patients requiring ventilation and a critical care bed during the first wave of the epidemic.
- The peak number of Covid-19 patients requiring oxygen in the first wave of the epidemic. This includes all patients requiring oxygen in hospital outside the critical care setting.
- The number of peak Covid-19 hospital admissions during the first wave of the epidemic.
- The number of Covid-19 deaths in the first 20 weeks of the epidemic.

This briefing note provides the modelling group's best judgement at a Northern Ireland level. The modelling assumes that current restrictions remain in place for the next six months, and future modelling will consider the implications of relaxing various restrictions at different time points. The modelling outputs for each individual Trust will be included in a bespoke appendix and circulated to each relevant individual Trust, along with this Northern Ireland level briefing note. It should be noted that modelling outputs for individual Trusts assume that the course of the epidemic is the same in all parts of Northern Ireland and does not account for the possibility of clusters emerging in individual Trust catchment areas. It is also important to note that the Trust outputs are based solely on relative population sizes and do not consider any influences for border regions with ROI.

Given the rapidly changing course of the epidemic and associated data flows, the group will update outputs on a weekly basis or at shorter intervals as required by emerging data.

NHS England Tool (*CovidUsageR*)

This model was created in parallel to the "NHSE/I impact on NHS usage" model (which the NI modelling group does not have access to). It was created for the purpose of duel running for quality assurance but with the intention to use this version for wider sharing and dissemination. The R code was authored and developed by Chris Pottage and Jonny Pearson.

The tool applies epidemic projection scenarios from a separate agent-based model by Ferguson *et al.* of Imperial College. The NHSE tool does not include the ability to run the Imperial model under different conditions but uses the outputs of that model. The group understands that the scenarios provided with the NHSE model are based on a R_0 of 2.4, which may be a low estimate of the basic reproduction number; and some

'spliced' scenarios in which the tool's authors merged and altered epidemic curves from different outputs of the Imperial model.

The model is underpinned by assumptions agreed by the Scientific Advisory Group for Emergencies (SAGE) and NHS England analysis of patient flow within hospitals.

Declan Bradley, Public Health Agency (PHA), has applied this tool to the Northern Ireland population using 2018 mid-year estimate population figures in 5-year age bands (Source: NISRA).

The model produces outputs starting from week 1 of a theoretical epidemic (in a wholly susceptible population). It is not directly tied to a specific start date. The model generates outputs for a range of outbreak scenarios that were provided by NHS England. The group understands that in version 2.3, for the scenarios based on the Ferguson *et al*. paper, the model assumes that the relevant measures (e.g. social distancing) were adopted from day one in the model. Three additional scenarios with different amounts of adherence to social distancing that were intended to be more realistic were also provided. Care should therefore be applied when interpreting the results as there is uncertainty about the applicability of the Ferguson *et al*. simulations to Northern Ireland (which was not included in their model), about the R_0 in the original data and about which week of the notional epidemic might "correspond" to the *real-time* evolving situation (and data).

Paul McWilliams / Strategic Investment Board Model

Paul McWilliams, a data analyst from the Strategic Investment Board, has developed a bespoke model for Northern Ireland, in the form of an extension to the well-known SIR model. The basic SIR model consists of three compartments: S for the number of susceptible, I for the number of infectious, and R for the number of recovered or deceased (or immune) individuals. These variables (S, I, and R) represent the number of people in each compartment at a particular time. To represent that the number of susceptible, infected and recovered individuals may vary over time, the model makes the precise numbers a function of t (time): S(t), I(t) and R(t). The rate of susceptible individuals moving into the infectious compartment depends on the R0 figure which estimates how many other individuals are infected by one infectious individual. A higher R0 value implies the disease will spread at a faster rate. This model will be used to triangulate interpretation of the NHS England model. As further Northern Ireland data becomes available, this model should become more stable. The modelling group expects to place increasing reliance on this model as it develops.

Simon Dodds (SaaSoft) Model

Simon Dodds, a healthcare systems engineer who has previously led quality improvement training for PHA, HSCB and Trusts, has created a system dynamics model of the outbreak and its impact on services. He has calibrated the model based on reported test positive results for Northern Ireland and provided some projections

that the modelling group will use as a sense-check for other sources of information. The group does not have access to the model itself.

Republic of Ireland Model

Discussions have also commenced with the Republic of Ireland on modelling the Covid-19 epidemic on an all-island basis. The RoI are using a Susceptible-Exposed-Infectious-Recovered (SEIR) differential equation compartment model which is being populated with data based on the observed spread of the epidemic in RoI.

Colleagues in the Republic of Ireland have agreed to run Northern Ireland data through their model and once outputs are available, these will be used to further calibrate the outputs from the NHS England model and inform judgements of the modelling group. In addition, the NI group will run RoI data through the NI model and provide outputs to them.

SCENARIOS

Best Case Scenario

This scenario assumes school closures, home isolation, quarantine and wider social distancing measures are in place and adhered to 100%. The table below sets out the modelling group's best judgements based on the modelling outputs currently available:

Table 1: Best Case Scenario

Description	Best Judgement
Peak number of Covid-19 patients requiring ventilation and **critical care beds** during the first wave of the epidemic	**80**
Peak number of Covid-19 patients requiring **oxygen** in the first wave of the epidemic	**170**
Peak number of Covid-19 **hospital admissions** during the first wave of the epidemic (per week)	**220**
Number of **cumulative** Covid-19 **deaths** in the **first 20 weeks** of the epidemic.	**251**

At the peak during wave 1, which occurs at week 9-10 (likely 6-20 April 2020), there will be 80 Covid-19 patients needing ventilation and a critical care bed. This number takes account of the assumed length of hospital stay. Similarly, there are expected to be 170 Covid 19 patients requiring oxygen at the peak of the first wave, again accounting for assumed length of hospital stay.

The modelling group do not consider this a realistic scenario. However, it provides a useful reference point for the minimum number of critical care beds needed at the peak, the likely peak Covid-19 hospital admissions and Covid-19 patients requiring oxygen.

Worst Case scenario

There is much more uncertainty around the reasonable worst case scenario. This is in a situation where the population do not adhere to social distancing measures.

Table 2: Worst Case Scenario

Description	Best Judgement
Peak number of Covid-19 patients requiring ventilation and **critical care beds** during the first wave of the epidemic	**500-1000**
Peak number of Covid-19 patients requiring **oxygen** in the first wave of the epidemic	**1150 - 2000**
Peak number of Covid-19 **hospital admissions** during the first wave of the epidemic (per week)	**1800**
Number of **cumulative** Covid-19 **deaths** in the **first 20 weeks** of the epidemic	**Up to 14,000**

The modelling group do not consider this a realistic scenario, although it provides a useful reference point for policy makers and an upper limit for adverse outcomes.

Reasonable Worst Case Scenario

The **Reasonable Worst-Case Scenario** assumes the following degree of compliance with current restrictions:

- School closures lead to an increase in contacts within the home by 100%
- Social distancing reduces contacts outside the home and workplace by 66%
- 50% of households adhere to household quarantine and 70% of symptomatic cases adhere to case isolation.
- Quarantined households and isolated individual cases reduce contacts outside the household by 75%.

It is assumed that current restrictions remain in place for the foreseeable future. When the current restrictions are relaxed, there will be a second wave. Future modelling will focus on the size and shape of this depending on how/when restrictions are relaxed or re-introduced. This will remain the case until there is substantial population immunity either as a result of recovery from infection or successful vaccination.

Based on emerging data the group, on the balance of probabilities, believe that the reasonable worst case scenario represents an upper limit for patient flows in wave one for critical care requirements and deaths. Insufficient NI data about hospital admissions is available to be confident about these in NI, but if patterns observed in England are confirmed for NI then this would also represent an upper limit for hospitalisations.

Table 3: Reasonable Worst Case Scenario

Description	Best Judgement
Peak number of Covid-19 patients requiring ventilation and **critical care beds** during the first wave of the epidemic	**180**
Peak number of Covid-19 patients requiring **oxygen** in the first wave of the epidemic	**400**
Peak number of Covid-19 **hospital admissions** during the first wave of the epidemic (per week)	**500**
Number of **cumulative** Covid-19 **deaths** in the **first 20 weeks** of the epidemic.	**3000**

At the peak during wave 1, which occurs at week 9-10 (likely 6-20 April 2020), it is expected that there will be 180 Covid-19 patients needing ventilation and a critical care bed. This number takes account of the assumed length of hospital stay. Similarly, there are expected to be 400 Covid 19 patients requiring oxygen at the peak of the first wave, again accounting for assumed length of hospital stay. Hospital admissions are expected to be 500 per week at the peak of the first wave.

Questions about this Briefing Note

If you have questions about this briefing note please contact Peter Jakobsen or NR NR.

Contact Details:

Peter.jakobsen@health-ni.gov.uk

NR @health-ni.gov.uk

Detailed Modelling Outputs

Detailed modelling outputs are currently available for the NHS England model and the Paul McWilliams / Strategic Investment Board model.

Please contact Ian Young / NR for further details of the model outputs for Northern Ireland.

Contact Details:

Ian.Young2@health-ni.gov.uk

Annex A

The Covid 19 modelling working group is comprised of:

Prof Ian Young (Chair) – Chief Scientific Advisor, DoH
Prof Adele Marshall, Professor of Statistics, Queens University Belfast (QUB)
Prof Frank Kee, Director, Centre of Excellence for Public Health, QUB
Paul McWilliams, Data analytics, Strategic Investment Board
Prof Hugo Wan Woerden – Director of Public Health, PHA
Dr Declan Bradley – Consultant, Health Protection, PHA
Janice Bailey – PHA
Peter Jakobsen, Director, DoH
NR Principal Economist, DoH

Further members may be added as necessary.