# COVID-19 Hospital Utilisation Planning model

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## Abstract

This technical note summarises the current version of the hospital service demand and capacity model that is used by the Irish Epidemiological Modelling Advisory Group (IEMAG) reporting to the National Public Health Emergency Team (NPHET). The model is continually updated, so this note supersedes previous versions, and will be superseded by future updates.

## Introduction

The COVID-19 hospital utilisation planning model was developed to assist with planning acute hospital capacity requirements during the outbreak. It is implemented in Microsoft Excel and draws on a range of datasets to generate demand and capacity projections. The model currently provides daily projections for up to 216 days from the start of the outbreak in Ireland. This note provides details of the data used in the model and the methods applied in it to project service demand and utilisation of acute hospitals.

## Methods

The model is a deterministic simulation that starts with county-level predictions of the number of cases diagnosed each day with COVID-19; these are normally generated separately using epidemiological models. To project the service demand associated with a given epidemic scenario, assumptions are required about the numbers of patients who will experience varying levels of severity of the illness and receive relevant levels of treatment. The main required assumptions are age- and sex-specific probabilities of admission to hospital and critical care, as well as average length of stay for each stage of the main care pathways. Given these assumptions, the model predicts the number of cases in each county requiring critical or non-critical acute hospital care on each day of the projection period. Assumptions about average length of stay in hospital and critical care are used to remove groups of individuals receiving each type of care on days after their hospital stays are completed. This results in predictions of county-level requirements for each type of treatment on each day.

For example, here is how projections of daily critical care demand are generated in the model:

$$ICU_t^r = \sum_{j=1}^{LOS1} p_1 C_{t-j}^r + \sum_{k=1}^{LOS2} p_2 C_{t-k}^r$$

In the equation, $ICU^r{}_t$ is the number of people requiring critical care in county $r$ on day $t$. $LOS1$ and $LOS2$ are lengths of stay for people who will survive and die, respectively. $p_1$ and $p_2$ are probabilities of cases admitted to critical care that will ultimately end in survival or death, respectively, $C^r{}_t$ is the predicted number of new cases in county $r$ on day $t$ from an epidemiological scenario, and $j$ and $k$ are indices to pick up the time since cases came into critical care units. Similar methods are used to project the number of patients requiring non-critical care beds.

County-level demands for care are mapped on to hospitals using a matrix showing the historical probability of a COVID-19 case from each county being treated in each hospital. The care provided in each hospital is assigned to a CHO area and a hospital group, providing projections of daily demand for each level of care in these regional groupings as well.

Non-COVID demand is not modelled, rather measures of the latest daily non-COVID occupancy are estimated and continually updated. The most recent estimates of the level of non-COVID occupancy are then assumed to represent the expected level of non-COVID occupancy for the remaining projection days.

Daily non-COVID critical care occupancy by hospital is estimated by subtracting COVID-occupied critical care beds from total occupied critical care beds.

Daily non-COVID general bed occupancy by hospital is estimated by subtracting the number of general vacant beds and the number of confirmed COVID-19 cases from total general open beds.

Implied daily requirements for key categories of staff in each hospital are based on assumptions about the hours of input from each staff category per patient day. Assuming static relationships between staff hours and activity, additional hospital demand due to COVID-19, measured as in-patient bed days is converted into additional staff hours.

Finally, the level of potential bed capacity, by hospital, available to meet the increased demand due to COVID-19 is considered. Capacity in each of the private hospitals can be assigned to the nearest Tier 1 public hospital, in scenarios in which private hospital capacity is available to meet COVID-19 demand. Capacity adequacy are displayed at CHO and hospital group level.

# Data

In this section, the main sources of data are outlined and their use in the model is described. Appendix 1 provides some details of current parameter values and a summary description of data sources that are used to inform the model. Appendix 2 gives further information on how some of the data sources are processed to arrive at parameter estimates.

## Epidemic curves

Epidemic predictions used in the model are provided by IEMAG Subgroup 1. The main set of scenarios currently used in the model are county-level predictions from a SEIR model of the number of new cases confirmed on each day. The county-level predictions are based on the methodology outlined in the IEMAG Technical Note "A population-level SEIR model for COVID-19 scenarios", 11 May 2020.

The current set of scenarios is listed in Table 1 and projected cases for each scenario are illustrated in Table 2. The scenarios illustrate growth in COVID-19 cases under different assumptions about how individual behaviours change as restrictions on the public are relaxed.

TABLE 1: Actual and predicted weekly average new confirmed COVID-19 cases per day for a range of epidemic scenarios

| Scenarios |
|---|
| 16a: Scenario a: R=0.7 for 9 weeks |
| 16b: Scenario b: R=0.9 for 9 weeks |
| 16c: Scenario c: R=1.1 for 9 weeks |
| 16d: Scenario d: R=1.2 for 9 weeks |
| 16e: Scenario e: R=1.4 for 6 weeks, then R=0.7 for 3 weeks |

| |
|---|
| 16f: Scenario f: R=1.6 for 4 weeks, then R=0.7 for 5 weeks |
| 16g: Scenario g: R=1.8 for 4 weeks, then R=0.7 for 5 weeks |

TABLE 2: Actual and predicted weekly average new confirmed COVID-19 cases per day for a range of epidemic scenarios

| | | Predictions by scenario | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Week starting | Actuals | 16a | 16b | 16c | 16d | 16e | 16f | 16g |
| 23/08/2020 | 114 | | | | | | | |
| 30/08/2020 | 131 | | | | | | | |
| 06/09/2020 | 187 | | | | | | | |
| 13/09/2020 | | 280 | 280 | 280 | 280 | 280 | 280 | 280 |
| 20/09/2020 | | 350 | 350 | 350 | 360 | 360 | 370 | 370 |
| 27/09/2020 | | 310 | 350 | 390 | 420 | 470 | 520 | 580 |
| 04/10/2020 | | 240 | 320 | 410 | 470 | 590 | 740 | 920 |
| 11/10/2020 | | 190 | 290 | 430 | 520 | 750 | 1050 | 1450 |
| 18/10/2020 | | 150 | 260 | 460 | 590 | 950 | 1470 | 2240 |
| 25/10/2020 | | 110 | 240 | 410 | 560 | 1010 | 1300 | 2050 |

*Source: predictions from SEIR models on 22 September 2020. Predicted values are rounded to the nearest 10 cases, sometimes resulting in zeros.*

## Demographic assumptions

The model includes estimates of the population for each local authority in 2020. These are estimates from the ESRI demographic model. The numbers of persons in 2020 are broken down by sex and single year of age. We aggregate these groups to 10-year age bands up to 80+.

## Care intensity parameters: treatment probability, treatment lag and average length of stay

For modelling purposes, the focus is on three COVID-19 patient groups:

(i) persons with moderate illness who require non-critical hospital care;
(ii) those with severe illness who spend time in critical care but subsequently recover; and
(iii) those who are admitted to, and later die in, critical care.

In principle, each COVID patient group could have varying lengths of stay at different points along the care pathway, i.e. hospital bed only, pre-critical care, critical care and post-critical care.

To account for age and sex variations in severity and treatment, average rates for three metrics by sex and 10-year age band up to 80+ are calculated from the Health Protection Surveillance Centre (HPSC) CIDR database (the current dataset covers the epidemic up to 15 September 2020). The metrics used, which are assumed to remain stable during the prediction period, are

(i) shares of total diagnosed cases made up by each demographic group; and
(ii) for each group, the share of diagnosed cases that does not require critical care treatment; and
(iii) the share that requires critical care treatment.

The model of care scenarios include probabilities of requiring treatment by age and sex, as well as length of stay for patients with varying levels of severity.

The first block of parameters describes the average probability that a diagnosed individual will, receive hospitalisation only, require ICU care but ultimately recover, or receive ICU care but ultimately die.

The second block of assumptions indicates how many days on average elapse between diagnosis and each level of care for those that receive it, and how long on average individuals receiving each type of care stay in the relevant facilities. We currently assume that individuals receive continuous care at a given level up to their length of stay. No provision is made for later readmission or transfer between hospitals.

Two scenarios for these parameters are included in the current version of the model (v4.35). Both make assumptions about the probabilities of being admitted to hospital or receiving critical care. These probabilities are set to the population-weighted sample average rates for each age/sex category. Both scenarios also have assumptions for average length of stay informed by averages from CIDR and HIPE. The main scenario ("HPSC Irish recent data") takes observed confirmed case data from July 2020 onwards. This main scenario therefore assumes the age and sex-specific rate of hospital admission and length of stay for projected COVID-19 cases follows recent trends. The second scenario ("HPSC Irish LR averages") takes observed confirmed case data over the course of the pandemic to date as a basis for projecting COVID-19 hospital demand. The second scenario therefore examines the impact on hospital demand if these parameters reverted to their long run values.

### Region-hospital mapping of admissions

The model contains a matrix showing the share of each region's diagnosed COVID cases that are assumed to go to each hospital in the country. This matrix is populated with data from an analysis of Hospital In-Patient Enquiry microdata that indicates the flows of cases from counties to hospitals over the course of the pandemic to date.

### Demand from conditions other than COVID-19 and restart parameters

Demand for non-COVID critical care is estimated from twice-daily NOCA ICU BIS extracts that report total and COVID occupied critical care beds by hospital, respectively. Estimated non-COVID general hospital bed demand relies on two main data sources:

(i) the February 2020 stock of general hospital beds compiled by HSE BIU and HSE Acute Operations; and
(ii) daily vacant general beds data reported through HSE COVID-19 daily operations updates.

While non-COVID demand is not modelled *per se* a functionality exists within the model to change the future level of non-COVID demand by specifying a hospital-specific growth rate for this activity, converging to a specific (user-defined) rate by the end of the projection horizon (e.g. 10% increase in non-COVID bed days by end September 2020).

### Baseline bed capacity in public hospitals

The February 2020 stock of open general beds, by hospital, reflects baseline general bed capacity in the model. These data were compiled by the HSE (Business Information Unit and Acute Hospital Operations) and provided to the ESRI by the Department of Health. The model captures 10,770 beds across the 26 Tier 1 hospitals included in the model.

Two main measures of public hospital critical care bed capacity are included in the model. The first measure captures the baseline pre-COVID stock of critical care beds. These data were provided

directly by NOCA based on the Critical Care Programme Census 2019[1] (updated by direct communication by NOCA with the units on 13 March 2020). In total the baseline critical care bed stock amounts to 255 beds.[2] The second measure of critical care capacity is more dynamic and captures the daily number of open critical care beds reported by NOCA-BIS. Open beds reflect beds on a particular day in use or ready for use and generally represents a proportion of the total NOCA-reported daily bed stock.

## Surge Capacity

The model also has the ability to activate Surge 1 critical care bed capacity. Data on additional potential surge bed capacity, by hospital, is taken from a NOCA survey conducted on 1 May 2020. Overall, this results in a 50 per cent expansion beyond baseline capacity. The activation of this level of surge reflects a scenario whereby non-ICU nurses and doctors are redeployed from normal responsibilities but supported adequately by ICU nurses and doctors. Quality of care provided to patients is maintained at normal levels.[3]

It is likely the activation of critical care surge capacity, through redeployment of resources, will have a significant impact on other activities within the hospital. It is difficult to quantity this effect, however, which is likely to vary by hospital. Our model at present takes no account of this potential interaction.

Information on private hospital bed supply has been provided by the Department of Health, based on a survey of all 18 private hospitals in Ireland. These data contain information on total in-patient beds and critical care beds (ICU/HCU) among other relevant capacity measures. We add hospital general bed (1,887) and critical care bed capacity (101) from each of the private hospitals to the nearest public hospital.

## Workforce requirement assumptions

The model includes assumptions about hours of each category of staffing required per patient day (e.g. Consultant, Nursing, NCHD). This is built up from HSE wholetime equivalent figures for each hospital in November 2019 multiplied by assumed hours of work, which is then divided by the number of cases treated at each level of care in the same month. Assumptions are made on the share of staff hours devoted to admitted hospital care, and within that, an assumed weighting towards in-patient care. For nursing hours ICU and non-ICU hours are considered separately. We assume 24-hour nursing support for ICU cases.

## Model validation

We use data from NOCA on actual cases receiving critical care to check whether the model is accurately projecting these demands nationally in the most recent days for which actual data are available. In addition, data from HSE Daily Operations Reports on the numbers of COVID patients being treated by each hospital group at 8pm daily is used to compare actual vs. projected total numbers of beds occupied by COVID patients in each hospital group. The preparation of these data is described in the appendix.

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1 https://www.hse.ie/eng/about/who/cspd/ncps/critical-care/critical-care-capacity-planning/national-adult-critical-care-capacity-census-2019-report.pdf

2 On advice from the HSE and NOCA, the model adopts a broad definition of critical care beds including both HDU (level 2) and ICU (Level 3) beds

3 Personal communication with Dr Rory Dwyer, National Clinical Lead, NOCA.

# Outputs

## Weekly average demand projections

The main output used to display projected service demand due to COVID-19 is a set of tables containing weekly averages for new cases, acute non-critical COVID bed days and critical care COVID bed days. This summary currently extends to the end of October 2020 (see Tables 3 and 4). The Results_Weekly worksheet shows these projections for all scenarios currently loaded into the model. These summary tables are generated and copied into tables by Visual Basic code when the scenarios are loaded.

Key assumptions taken from CIDR data for confirmed cases from July 2020 onwards.: 2.6% of cases admitted to hospital; 10.8% of those in hospital require critical care.

TABLE 3: Projected weekly average demand for critical care beds due to COVID-19 based on a range of epidemic scenarios - HPSC Irish recent data scenario

| | Predictions by scenario | | | | | | |
|---|---|---|---|---|---|---|---|
| **Week starting** | **16a** | **16b** | **16c** | **16d** | **16e** | **16f** | **16g** |
| 13/09/2020 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 20/09/2020 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 27/09/2020 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 04/10/2020 | 10 | 20 | 20 | 20 | 20 | 30 | 30 |
| 11/10/2020 | 10 | 10 | 20 | 20 | 30 | 40 | 50 |
| 18/10/2020 | 10 | 10 | 20 | 30 | 40 | 50 | 70 |
| 25/10/2020 | 10 | 10 | 20 | 30 | 50 | 70 | 110 |

*Source: predictions from CHUP model v4.45. Values are rounded to the nearest 10 cases, sometimes resulting in zeros.*

TABLE 4: Projected weekly average demand for general acute hospital beds (non-critical care) due to COVID-19 based on a range of epidemic scenarios - HPSC Irish recent data scenario

| | Predictions by scenario | | | | | | |
|---|---|---|---|---|---|---|---|
| **Week starting** | **16a** | **16b** | **16c** | **16d** | **16e** | **16f** | **16g** |
| 13/09/2020 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 20/09/2020 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| 27/09/2020 | 100 | 100 | 110 | 110 | 110 | 120 | 120 |
| 04/10/2020 | 90 | 100 | 120 | 130 | 150 | 170 | 190 |
| 11/10/2020 | 70 | 100 | 130 | 140 | 190 | 240 | 310 |
| 18/10/2020 | 60 | 90 | 130 | 160 | 240 | 340 | 480 |
| 25/10/2020 | 40 | 80 | 140 | 180 | 300 | 440 | 660 |

*Source: predictions from CHUP model v4.45. Key assumptions taken from CIDR data for confirmed cases from July 2020 onwards: 2.6% of cases admitted to hospital; 10.8% of those in hospital require critical care. Values are rounded to the nearest 10 cases, sometimes resulting in zeros.*

## Graphical results – national level

In addition, some national summary time series plots are included in the Main worksheet. These relate to the current selected scenario:

- Charts and tables comparing required and available beds nationally for hospital beds in general and for ICU beds;

- Charts and tables listing the number of additional hours required daily due to COVID-19 for each type of healthcare staff; and
- A table controlled by a drop-down menu that allow the user to view the adequacy of beds and ICU across all Tier 1 public hospitals on an individual day and a set of charts that allow the user to view bed adequacy over time for a selected CHO region.

For example, Figure 1 below illustrates the projected requirement and availability of critical care beds nationally under the $R_t$=1.2 (16d) and 1.6 (16f) scenarios discussed above.

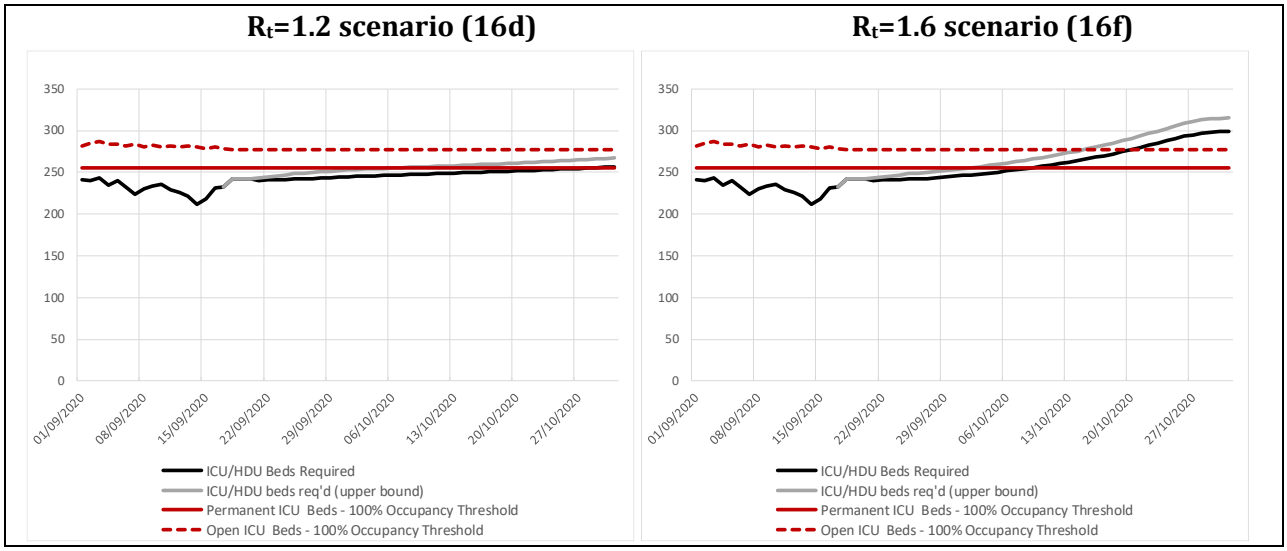


FIGURE 1: Actual and projected national demand and capacity for critical care beds in Scenarios 16d and 16f. Note: the open beds projection is based on current levels of availability and does not include surge capacity.

## Regional utilisation indicators

A set of regional summary indicators are provided on the Results worksheet:

- A table projecting the week in which hospital bed and ICU capacity will be exceeded in each CHO region and hospital group under the selected scenario; and
- Attack rates nationally and by county for the most recent fortnight and the upcoming fortnight, based on the day of the outbreak that has been selected.

# Appendix 1 – Parameter values for the current set of scenarios used in the model and description of key data used to inform model inputs

## A1. Model of care scenario using data from Ireland

TABLE below shows the assumed probabilities associated with three types of hospital attendance associated with a COVID-19 diagnosis, split by age band and sex. The probabilities of hospitalisation and of requiring ICU care are the average values taken from the HPSC CIDR database for confirmed cases from July 2020 onwards. A weighted average by population yields a probability of 2.6% of hospital admission, with 10.8% of the hospitalised group being admitted to critical care. We further assume that 85% of those who require critical care ultimately survive. This is intended to represent a long-term average rate.

**TABLE A1** Probabilities of three classes of hospital attendance by age band and sex, HPSC Irish data scenario, 15 September 2020

| | | Age bands | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0- 9 | 10-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70-79 | 80+ |
| Female | Hospitalisation only | 2.8% | 1.0% | 1.6% | 0.7% | 1.4% | 2.3% | 6.1% | 10.3 % | 12.3% |
| | Critical care & recovery | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.9% | 0.0% | 0.8% | 0.0% |
| | Critical care & death | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.2% | 0.0% | 0.1% | 0.0% |
| Male | Hospitalisation only | 1.2% | 0.5% | 0.9% | 1.5% | 0.9% | 3.4% | 3.4% | 16.3 % | 25.0% |
| | Critical care & recovery | 0.3% | 0.0% | 0.1% | 0.3% | 0.4% | 0.5% | 0.4% | 3.5% | 0.0% |
| | Critical care & death | 0.1% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.6% | 0.0% |

*Source: Analysis of HPSC CIDR dataset up to 15 September 2020.*

Assumptions about average length of stay in the scenario are shown in TABLE A2 below. These assumptions are informed by averages from CIDR and HIPE data but also checked by calibrating the model to match the number of critical care and non-critical care beds occupied by COVID-19 patients.

**TABLE A2** Assumptions about average length of stay (LOS) spent at different points along care pathway, HPSC Irish data scenario

| Parameter | Days |
|---|---|
| Time from diagnosis to hospitalisation | 0 |
| LOS pre-ICU | 1 |
| LOS for those requiring only non-critical care | 12 |
| LOS for those who require critical care and survive | 11 |
| LOS for those who require critical care and die | 11 |
| LOS post-critical care for those who survive | 5 |

*Source: Analysis of HPSC CIDR, and HIPE, datasets – 15 September2020*

## A2. Model of care scenario using data from Ireland

Assumptions regarding acute staffing hours per patient day are shown in Table A3. These ratios are calculated from HSE WTE figures for each hospital in November 2019 multiplied by assumed hours of work, which is then divided by the number of cases treated at each level of care in the same month. Assumptions are made on the share of staff hours devoted to admitted hospital care, and within that, an assumed weighting towards in-patient care. For nursing hours, ICU and Non-ICU hours are considered separately. 24-hour nursing support for ICU cases is assumed.

**TABLE A3** Assumptions about acute staffing hours per patient, by staff category

| Parameter | Hours |
|---|---|
| Non-ICU Nursing Hours per Patient Day | 7.5 |
| ICU Nursing Hours per Patient Day | 24.0 |
| Consultant Hours per Patient Day | 0.8 |
| Registrar Hours per Patient Day | 0.8 |
| SHA/Intern Hours per Patient Day | 0.8 |
| Total Doctor Hour per Patient Day | 2.4 |

## Allocation matrix of confirmed COVID-Cases

Table A4 represents a matrix populated with data from an analysis of HIPE microdata that indicates the flows of COVID cases from counties to hospitals over the course of the pandemic to date. The matrix is continually updated with latest available data on case flows to hospitals recorded in the HIPE database.

**TABLE A4** Matrix of the historical probability of a COVID-19 case from each county being treated in each hospital as of 15th September 2020

| | HIPE Hospital ID | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | **4** | **5** | **7** | **21** | **22** | **37** | **41** | **100** | **101** | **103** | **105** | **203** | **235** | **236** | **303** | **403** | **404** | **405** | **501** | **503** | **506** | **601** | **602** | **701** | **702** | **705** |
| Carlow | 0.02 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cavan | 0.00 | 0.03 | 0.00 | 0.01 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.87 | 0.05 |
| Clare | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cork | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.62 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Donegal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.03 | 0.00 | 0.00 | 0.00 |
| Dublin | 0.00 | 0.25 | 0.14 | 0.14 | 0.10 | 0.20 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Galway | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.89 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Kerry | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Kildare | 0.47 | 0.04 | 0.01 | 0.04 | 0.23 | 0.02 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Kilkenny | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.08 | 0.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Laois | 0.00 | 0.00 | 0.03 | 0.06 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.06 | 0.15 | 0.00 | 0.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Leitrim | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.84 | 0.00 | 0.11 | 0.00 |
| Limerick | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Longford | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.03 |
| Louth | 0.00 | 0.06 | 0.00 | 0.02 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 0.00 | 0.00 |
| Mayo | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| Meath | 0.01 | 0.13 | 0.00 | 0.02 | 0.27 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.00 | 0.00 | 0.00 | 0.15 | 0.03 | 0.31 |
| Monaghan | 0.00 | 0.03 | 0.02 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 | 0.64 | 0.00 |
| Offaly | 0.02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.80 | 0.08 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Roscommon | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.17 | 0.03 | 0.07 | 0.07 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sligo | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.97 | 0.00 | 0.00 | 0.00 |
| Tipperary | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.00 | 0.00 | 0.19 | 0.01 | 0.00 | 0.00 | 0.60 | 0.01 | 0.00 | 0.00 | 0.03 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Waterford | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.71 | 0.00 | 0.00 | 0.13 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Westmeath | 0.00 | 0.01 | 0.00 | 0.09 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.22 | 0.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wexford | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.82 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wicklow | 0.05 | 0.08 | 0.74 | 0.03 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

## A4. Projected weekly average demand for critical care and general beds due to COVID-19 –HPSC LR averages

Table A6 provides alternative projections of general (non-critical care) and critical care beds across a range of epidemic scenarios should admission probability and resource use parameters revert to their long-run averages over the course of the pandemic to date.

**TABLE A6** Projected weekly average demand for critical care and general (non-critical care) acute hospital beds due to COVID-19 based on a range of epidemic scenarios - HPSC LR averages

| Predictions by scenario | | | | | | |
|---|---|---|---|---|---|---|
| **Critical Care Beds** | | | | | | |
| **Week starting** | 16a | 16b | 16c | 16d | 16e | 16f |
| 13/09/2020 | *80* | *80* | *80* | *80* | *80* | *80* |
| 20/09/2020 | *100* | *100* | *100* | *100* | *100* | *100* |
| 27/09/2020 | 120 | 120 | 130 | 130 | 130 | 130 |
| 04/10/2020 | 120 | 130 | 140 | 150 | 170 | 180 |
| 11/10/2020 | 100 | 120 | 150 | 170 | 210 | 260 |
| 18/10/2020 | 80 | 110 | 160 | 190 | 270 | 370 |
| 25/10/2020 | 60 | 100 | 170 | 210 | 340 | 500 |
| **General (non-critical care) Beds** | | | | | | |
| **Week starting** | 16a | 16b | 16c | 16d | 16e | 16f |
| 13/09/2020 | *280* | *280* | *280* | *280* | *280* | *280* |
| 20/09/2020 | *380* | *380* | *380* | *380* | *380* | *380* |
| 27/09/2020 | 450 | 470 | 490 | 500 | 520 | 540 |
| 04/10/2020 | 430 | 490 | 550 | 590 | 670 | 760 |
| 11/10/2020 | 360 | 460 | 590 | 670 | 850 | 1070 |
| 18/10/2020 | 290 | 430 | 630 | 750 | 1070 | 1510 |
| 25/10/2020 | 230 | 390 | 660 | 840 | 1360 | 1940 |

*Source: predictions from CHUP model v4.45. Key assumptions taken from CIDR data for confirmed cases over the course of the pandemic: 12.0% of cases admitted to hospital; 13.1% of those in hospital require critical care. Values are rounded to the nearest 10 cases, sometimes resulting in zeros.*

# A5. Data Sources

**TABLE A6** Data Sources informing the CHUP model

| Data Source | Data | Data Description | Data collected |
|---|---|---|---|
| **IEMAG Subgroup 1** | Epidemic Curves | County level predictions from SEIR model of number of new COVID-19 cases per day | N/A |
| **ESRI Demographic Model** | Population Data | Local authority level single year of age and sex population estimates for 2020 | N/A |
| **CIDR Database** | Probability of Hospital and ICU Admission | 10-year age bands and sex | Daily updated* |
| | Probability of Death in ICU | 10-year age bands and sex | |
| | ICU ALOS | Overall ALOS and by Decedent/Survivor status | |
| **HIPE Database** | Hospital Allocation Matrix | Historic probability of a COVID-19 case from each county being treated in each Tier 1 public hospital | Daily updated* |
| | General hospital ALOS | Overall ALOS | |
| **HSE Daily Operations Report** | Vacant Beds | Count of vacant general beds by hospital | Daily updated |
| | COVID-19 Confirmed Cases | Count of COVID-19 cases by hospital | |
| **HSE BIU/Acute Operations** | General Beds | Count of general beds by hospital | February 2020 |
| **NOCA ICU-BIS** | Open and Occupied Critical Care Beds | Count of open and occupied critical care beds by hospital | Daily updated |
| | COVID-19 Occupied Critical Care Beds | Count of COVID-19 confirmed occupied critical care beds by hospital | |
| **NOCA ICU Survey** | Surge Capacity | Estimates of available additional bed surge capacity by hospital | May 2020 |
| **Private Hospital Survey** | Critical Care Beds | Count of critical care beds by hospital | March 2020 |
| | General Beds | Count of General beds by Hospital | |
| **HSE Personnel Census** | Acute Hospital WTE | Acute hospital WTE by staff category and hospital | November 2019 |

*Note:* Given the low number of new cases, since July 2020 CIDR and HIPE have moved to once-weekly updating of their datasets provided through the CSO

# Appendix 2 – Data Preparation

## Hospital admission probabilities by age and sex band

CIDR microdata is loaded from the most recent HPSC extract file (CIDR_all_*.xlsx) file and a SQL query is run on it:

SELECT Cases_new.Sex, AgeBands.AgeBand, Count(Cases_new.ID) AS Cases, Sum(IIf([Hospital] Is Null,0,[Hospital])) AS Hospitalised, Sum(IIf([Was the case admitted to ICU]="Yes",1,0)) AS ICU FROM (PatientType INNER JOIN Cases_new ON PatientType.[Patient Type] = Cases_new.[Patient Type]) INNER JOIN AgeBands ON Cases_new.[Age (Years) at time of event] = AgeBands.Age GROUP BY Cases_new.Sex, AgeBands.AgeBand;

## Actual number of cases in each county

CIDR microdata is loaded from the most recent HPSC extract file (CIDR_all_*.xlsx) file and a SQL query is run on it:

TRANSFORM Count(Cases_new.ID) AS CountOfID SELECT Cases_new.[County (Event)] FROM Cases_new GROUP BY Cases_new.[County (Event)] PIVOT Cases_new.[Event Date];

## Actual number of cases in each hospital by day

HSE Daily Operations Report microdata is loaded cumulatively from all 8pm extract files to date (COVID_Hospital_list*.xlsx) files and a SQL query is run on the resulting database:

TRANSFORM Sum(Hospital_Activity.[Number of confirmed COVID 19 cases Admitted on site]) AS [Covid admissions] SELECT Hospitals.HospCode, Hospitals.Hospital FROM Hospitals INNER JOIN Hospital_Activity ON Hospitals.Hospital = Hospital_Activity.Hospital WHERE (((Hospitals.HospCode) Is Not Null)) GROUP BY Hospitals.HospCode, Hospitals.Hospital PIVOT Hospital_Activity.Date;

## Actual number of vacant beds in each hospital by day

HSE Daily Operations Report microdata is loaded cumulatively from all 8pm extract files to date (COVID_Hospital_list*.xlsx) files and a SQL query is run on the resulting database:

TRANSFORM Sum(Hospital_Activity.[Updates::novacantbeds 8am]) AS [SumOfUpdates::novacantbeds 8am] SELECT Hospitals.HospCode, Hospitals.Hospital FROM Hospital_Activity RIGHT JOIN Hospitals ON Hospital_Activity.Hospital = Hospitals.Hospital WHERE (((Hospitals.HospCode) Is Not Null)) GROUP BY Hospitals.HospCode, Hospitals.Hospital PIVOT Hospital_Activity.Date;

## Region-Hospital Matrix

The Region-Hospital Allocation Matrix is updated based on latest available HIPE microdata. The matrix is based on data analysis of discharged COVID-confirmed cases since 1st April 2020 using STATA 15:

```
Levelsof hospital if ED_247 ==1, local(levels)
foreach l of local levels {
preserve
collapse (count)count_case if hospital == `l' & admdate_N > 86, by(pop_region_1)
```

```
rename count_case h_`l'
merge 1:1 pop_region_1 using region_hosp_matrix, nogenerate
save region_hosp_matrix, replace
restore
}

use region_hosp_matrix, clear
egen N_total = rowtotal(h_705 – h_4)
foreach var of varlist h_705 – h_4 {
replace `var' = 0 if `var' ==.
gen p`var' = `var'/N_total
}
egen P_total = rowtotal(ph_705 – ph_4)
preserve
keep pop_region_1 N_total ph_705 – ph_4
order pop_region_1 ph_705 – ph_4 N_total
sort pop_region1
export excel using "C:\Users\keeganc_ext\Desktop\CIDR\region_hosp_matrix_02072020.xlsx", ///
sheet ("region_hosp_ED247_HIPE_Apr") firstrow(variables) sheetmodify
restore
```

## Length of Stay in ICU

Parameters estimates for ICU LOS are taken from the latest available HPSC CIDR microdata. Analysis is undertaken in STATA 15. Although not shown, this code can also be filtered accordingly for Survivors and Decedents:

```
local row = 2
foreach i in 0 31 61 92 122 153 {
capture sum los if event_day >= `i'
putexcel set LOS_descriptives_26082020.xlsx, sheet(All CIDR) modify
putexcel A1 = "Event Day"
putexcel B1 = "Mean LOS"
putexcel C1 = "Standard Deviation"
putexcel D1 = "Min"
putexcel E1 = "Max"
putexcel F1 = "Obs"
local ++row
putexcel A`row' = `i'
putexcel B`row' = `r(mean)'
putexcel C`row' =  `r(sd)'
putexcel D`row' = `r(min)'
putexcel E`row' = `r(max)'
putexcel F`row' = `r(N)'
bootstrap r(mean), reps(500): capture sum los if event_day >= `i'
putexcel G1 = "Lower Bound - Bootstrap"
putexcel H1  = "Higher Bound - Bootstrap"
matrix table_`i' = r(table)
```

```
matrix a_`i' = table_`i'[5,1]
putexcel G`row' =  matrix (a_`i')
matrix b_`i' = table_`i'[6,1]
putexcel H`row'  = matrix (b_`i')


}
```