

COVID-19 Essential Supplies Forecasting Tool

Overview of the structure, methodology, and assumptions used

Interim guidance
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Summary

This document provides technical details and methodological explanations on the structure of the COVID-19 Essential Supplies Forecasting Tool (ESFT). It is intended to provide information that will allow users to a) trace and understand the calculations, assumptions, and limitations of ESFT; and b) modify these assumptions for different contexts or use cases.

Inputs Tab

Structure

- All user entry is in column C, blue cells;
- All reference values are in column E;
- All values that feed the calculations in the model pull from the corresponding row, but in column I (which is locked and has white text so is not visible to users);
- This formula allows for a) the use of the toggle button to switch between manual vs. default inputs; and b) overriding errors/gaps if a user accidentally leaves an input in column C empty (in which case it will pull the default);
- Inputs are bucketed by area to allow for easier navigation.

Methodology

Parameters entered constrain the demand forecast by:

- HCW constraints limit the number of HCWs forecast per week, capped by the maximum available, and thus constrains a) the PPE forecast and b) the HCW forecast;
- Bed constraints limit the number of patients forecast as admitted per week, capped by beds available for patients by severity, and thus constrains a) the biomedical equipment forecast and b) the severe/critical inpatient forecast;
- Diagnostic test absorption capacity constrains the number of diagnostic tests forecast per week, capped by the absorption capacity, and thus constrains a) the diagnostic consumables forecast, and b) the mild/moderate outpatient diagnosis (of note is that 'presumptive diagnosis' is used for severe/critical patients so equipment is forecasted for these patients independent of whether they were able to be tested for COVID-19 or not, provided there is bed space).

Assumptions

Patients and case severity

The model assumes a breakdown of case severity¹ among four patient types: mild, moderate, severe, and critical. Of note, is that we assume patients remain in the same case severity category throughout; we do not model the transition of patients between different levels of severity, e.g., being mild for two weeks, then severe for one week, then critical for one week, then recovered.

Case Severity	%
% <u>Mild</u> (isolation)	40%
% <u>Moderate</u> (isolation)	40%
% <u>Severe</u> (inpatient, needs O2)	15%
% <u>Critical</u> (inpatient, ventilation)	5%

¹ WHO, Interim Guidance, Operational Considerations for Case Management of COVID-19 in health facility and the community, 19 March 2020. Last accessed: https://apps.who.int/iris/bitstream/handle/10665/331492/WHO-2019-nCoV-HCF_operations-2020.1-eng.pdf

Due to the structure of the model, we model length of stay² in whole numbers of weeks, rather than the number of days, and assume an average number of weeks.

Length of Stay	# Weeks
Mild case (isolation)	2
Moderate case (isolation)	2
Severe case (hospitalized duration)	1
Critical case (hospitalized duration)	2

The case fatality rate is used in the calculation of the number of tests needed for discharge of severe and critical patients. We assumed the same severe fatality rate as was observed in Wuhan, China.³ The case fatality rate for critical patients has varied between 50-81%⁴ in different settings; we aligned with Imperial College modelling⁵ for the critical fatality rate.

Case Fatality Rates	%
Severe fatality rate (%)	13.4%
Critical fatality rate (%)	50%

Health care workers (HCW) and staff

The model provides a prompt to the user of the number of HCWs available in the country based on the reported number of doctors in the nurses in the WHO Global Health Observatory (GHO) dataset⁶. We adopted the following process for cleaning data to produce a reference value for each country:

- WHO GHO data is reported as the absolute number of nurses and doctors in a country in a given year. We calculated the five-year average population growth rate, using UNDP population growth from 2015 to 2020 for each country to give an 'average year-on-year growth rate' for each country (five-year average used to minimize effects of anomalous years). We multiplied the reported absolute number of nurses and doctors by the compound growth rate calculated by the delta between reporting year and 2020, using the calculated average year-on-year growth rate. This approach was used to scale nurse numbers to reflect changes in populations and potential corresponding growth in nurse numbers.
- If no value was reported in the relevant dataset, the average value per 1000 population for the income group was taken (as below for manual populations) and multiplied by the population in 2020.

If a user is modelling a manual population size, the model applies the global average for doctors and nurses per capita to the manually entered population size. These averages are based on the same datasets and are as follows:

Income category	Average of doctors per 1000 population, for territories with missing data	Average of nurses per 1000 population, for territories with missing data
Low income	0.379	0.874
Lower middle income	0.747	1.976
Upper middle income	2.108	3.859
High income	3.339	8.452
Manual	3.788	1.639

Note that we recognize that a broader range of HCWs than just nurses and doctors will be involved in the COVID-19 response. However, due to a) variation in health workforce response activities to COVID-19 globally, b) limitations in availability and quality

² WHO Health Emergencies Program

³ WHO China Joint Mission Report

⁴ Clinical course and outcomes of critical ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective observational study (Yang et al., 2020)

⁵ Imperial College, Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand

⁶ https://apps.who.int/gho/data/node.main.HWFGRP_0040?lang=en

of broader datasets (e.g., community health workers are poorly reported), and c) the focus of the ESFT being inpatient and screening/triage essential supply forecasting, we used nurses and doctors for estimating HCW numbers. These can be overridden if the user has more accurate information available.

Users are prompted to enter the % of HCWs not activated for COVID-19 response, with a prompt that this could be around 40%. Once again, due to high-levels of uncertainty and likely strong variation in this number, we advise users to refer to more accurate in-country numbers. The 40% figure was determined through consultation with medical professionals in a few countries (e.g., Nigeria, United Kingdom, Ethiopia, and United States).

Estimated HCW and cleaner staff ratios per bed were calculated using adapted assumptions from the WHO Health Workforce Estimator tool (HWFE)⁷ for the LMIC context based on consultant with expert clinicians in LMICs. The HWFE documents the patient time required per 24-hours by patient severity type for a broad range of medical professionals and cleaning/helping staff. To simplify, we grouped all medical professionals as HCWs and all non-medical professionals as cleaners before summing the total time required per patient. This approach was taken and reviewed for LMICs specifically, to give 18.2 hours for severe patients and 32.7 hours for critical patients. We assumed 8-hour shifts per staff members to calculate the number of HCWs and cleaners per bed. We then take the weighted average for critical and severe beds (which is fed by the input patient severity split, as above) in order to arrive at a single proposed value for HCW and cleaners required per bed in an inpatient ward.

Estimated Ambulance Personnel and Biomedical Engineer assumptions were calculated based on assumptions provided by WHO (Operations, Supply & Logistics [OSL] and biomedical team) for the number of each type of staff per 100 beds on average; again assuming 8-hour shifts.

Hospital infrastructure

The model uses the World Bank dataset for absolute number of beds⁸ and Imperial College estimates by income group for the % of beds that are ICU/critical⁹. Where there was no recorded data in the World Bank dataset for a territory, we use Imperial College reported averages per income group, as follows:

Income category	Proxy of total beds/1000 people, if not reported	Estimated % of total beds that are ICU/Critical (%)
Low income	1.24	1.63
Lower middle income	2.08	2.38
Upper middle income	3.41	3.32
High income	4.82	3.57

The model uses the same assumption on split of non-COVID-19 to COVID-19 beds as used for HCWs, namely 40% not allocated to COVID-19 and the remaining 60% allocated to COVID-19 response. Once again there is likely strong variation in this figure per country, and users are advised to adapt the inputs for their given setting based on known information.

Labs and Testing

The ESFT contains an embedded laboratory module, which estimates the maximum daily number of COVID-19 tests able to be conducted in each country based on available information on diagnostic absorption capacity. The output of this module (“max number of tests per day”) automatically flows into the ESFT as a “cap” on the total number of tests needed for a given scenario. If this value is not overridden by the user, the ESFT will not quantify for more tests than a country can absorb based on current capacity. The reference values for the module were taken from an assessment of available equipment and are based on a number of factors including population size, HIV burden (as many machines were initially purchased for HIV testing), and testing platforms known to the WHO. Please note that the reference values are estimates and may not exactly match the number of platforms in each country.

Users enter existing lab capacity metrics such as number of machines available for COVID-19 testing (high-throughput, near-patient, manual, and an “other category”), the number of shifts per day, the number of days the machines are run each week, and what percent of the total machine capacity could be utilized for COVID-19. Based on these inputs, the module calculates the estimated maximum number of COVID-19 tests that can be conducted per day.

If users would like to model *additional* capacity because of purchasing new (near-patient and/or manual) platforms, users enter in the estimated number of new machines in the “Additional Capacity per Day” module. These machines will be included in the ESFT commodity quantification, and the increase in capacity will be displayed under the module on the Input tab. This increase in capacity can then be fed back into to ESFT via the “User Input Maximum # Tests per Day” cell.

⁷ <http://www.euro.who.int/en/health-topics/Health-systems/pages/strengthening-the-health-system-response-to-covid-19/surge-planning-tools/health-workforce-estimator-hwfe>

⁸ <https://data.worldbank.org/indicator/SH.MED.BEDS.ZS>

⁹ Imperial College, Report 12: The Global Impact of COVID-19 and Strategies for Mitigation and Suppression

Lab staff availability is referenced through data from the WHO GHO dataset (referring to Medical and Pathology Laboratory Technicians, ILO ISCO 3212). Once again, where data was lacking for a given country, it is estimated by taking the average for the country's income group, as follows:

Income category	Number of Lab staff/1000 population for unreported countries
Low income	0.095
Lower middle income	0.258
Upper middle income	0.213
High income	0.533
Manual	0.275

The reference value for the number of labs conducting COVID-19 testing (used to calculate the number of lab staff and cleaners and associated PPE and equipment needs) uses the assumption that there is one lab for every three manual, high-throughput, and/or "other" platforms, and one lab for every four GeneXpert modules.

Assumptions on lab operations (staff per lab, equipment per hospital unit, and wastage) were all provided by the WHO Emergency Response team.

Oxygen use

The model proposes default O2 flow rates per bed for severe and two different rates for critical beds, with inputs from the WHO Clinical and Biomedical pillar leads. Initially, critical patients were assumed to require different flow rates: 50% on 30 LPM and 50% on a higher rate of 48 LPM. However, due to feedback from countries on reasonable flow rates, these were both switched to the lower rate of 30 LPM in the default assumptions. Users can also adjust the percent of critical patients receiving invasive mechanical ventilation (currently set to two-thirds of critical patients) and those receiving non-invasive ventilation (currently set to one-third of critical patients), and the subsequent flow rate for each type of critical patient.

We do not include the ability to constrain biomedical equipment forecast or critical patient forecast through entering in a) power, b) oxygen supply, or c) health workforce intubation/other critical care activity capacity. This results in an overestimation in the forecast, and may be addressed either in future iterations, or through use of complementary tools and models developed elsewhere.

Equipment List & Usage Tab

Structure

Equipment groupings: Equipment items are grouped into the following categories:

- Hygiene
- PPE
- Diagnostics
- Biomedical equipment, consumables & accessories
- Drugs

These categories are listed vertically in column C, with each item within each category broken down, in column D

Settings of care: Equipment items are modelled by the following settings of care:

- Inpatient care
- Isolation
- Screening/triage
- Laboratories

These settings of care are listed horizontally in row 13, with each setting of care broken down into different users of equipment in row 14

Usage assumptions: Usage assumptions should be interpreted as follows for each individual user:

- *HCW:* usage of an item per **shift** per HCW
- *Cleaner:* usage of an item per **shift** per cleaner
- *Informal caregiver:* usage of an item per **day** per informal caregiver (in days vs. shifts since informal caregivers do not rotate over time)
- *Ambulance personnel:* usage of an item per **shift** per ambulance personnel
- *Biomedical engineer:* usage of an item per **shift** per engineer

- *Severe patient*: usage of an item per **stay** per severe patient, i.e., each severe patient uses a certain amount of these items, and they cannot be reused between patients
- *Critical patient*: usage of an item per **stay** per critical patient, i.e., each critical patient uses a certain amount of these items, and they cannot be reused between patients
- *Both patients*: usage of an item per **stay** per severe and critical patient i.e., each inpatient uses a certain amount of these items per day, and they cannot be reused between patients
- *Severe bed*: placement/availability of an item per **severe bed**, i.e., each severe bed has a certain number of items allocated for it for occasional/periodic use with any number of severe patients lying in that bed over time
- *Critical bed*: placement/availability of an item per **critical bed**, i.e., each critical bed has a certain number of items allocated for it for occasional/periodic use with any number of critical patients lying in that bed over time
- *Both beds*: placement/availability of an item per **severe and critical bed**, i.e., each inpatient bed has a certain number of items allocated for it for occasional/periodic use with any number of patients lying in that bed over time
- *Patient*: usage of an item per **day** per mild/moderate patients
- *Laboratory technician*: usage of an item per **shift** per technician

Default assumptions on usage of equipment are entered in the appropriate grid in the matrix.

Some examples to explain how to read this information:

- *Cell K16*: Cleaners require 0.03 L of alcohol-based hand rub per shift (based on the assumption that 1 liter will last 30 days)
- *Cell R54*: 0.25, i.e., 1/4 of all severe beds have a patient monitor without ECG
- *Cell O74*: 0.67, i.e., 2/3 of all severe patients require a nasal oxygen cannula

Methodology

Usage assumptions (per shift, per bed, per day – as above) are multiplied through by the appropriate number of shifts/beds/people then multiplied by the length of the forecasting period to give the total. In detail:

- *For Inpatient HCW, Cleaner, Informal caregiver, Ambulance Personnel and Biomedical engineers*: through MMULT (matrix multiplication) of the values in columns J:N in the ‘Equipment List & Usage’ tab with the values in BF110:114 in the ‘Weekly summary’ numbers. This is then multiplied by 7 to get the total, since usage is in shifts/day and HCW & Staff numbers are in weeks.
- *For severe, critical and both patients; and severe, critical and both beds*: values in column O:T are multiplied by the relevant counterpart taken from the ‘Weekly summary’ tab, namely:
 - *Severe patient* usages are multiplied by the total number of severe patients admitted to beds over the forecast period (capped by bed availability over time) from BF50
 - *Critical patient* usages are multiplied by the total number of critical patients admitted to beds over the forecast period (capped by bed availability over time) from BF51
 - *Both patient* usages are multiplied by the total number of patients occupying beds summed over the forecast period (capped by bed availability over time) from BF64
 - *Severe beds* usages are multiplied by the maximum number of severe beds occupied at any one time (capped by parameters in the inputs) from BH62
 - *Critical beds* usages are multiplied by the maximum number of critical beds occupied at any one time (capped by parameters in the inputs) from BH63
 - *Both beds* usages are multiplied by the maximum number of beds occupied at any one time (capped by parameters in the inputs) from BH64
- The totals per item are summed together in columns BE and BF in the ‘Equipment List & Usage’ tab and these flow through to the outputs in the ‘User Dashboard’ tab.

Assumptions

Hygiene usage assumptions were all provided by WHO OSL, based on rational use of items on the COVID-19 Disease Commodity Package.¹⁰

PPE usage assumptions were initially provided by WHO OSL, based on rational use of items on the COVID-19 Disease Commodity Package for v1 of the ESFT. These were subsequently reviewed and updated by the Infection Control and Prevention (IPC) experts at WHO.

Diagnostic usage assumptions were all provided by WHO OSL and reviewed by diagnostics technical experts at WHO.

Biomedical equipment, consumables and accessories assumptions were all provided by the WHO biomedical and clinical teams and their supporting partners through close discussion and consultation. A few nuances to highlight:

- The items detailed match those in the WHO Priority Medical Device list at time of publication

¹⁰ [https://www.who.int/publications-detail/disease-commodity-package---novel-coronavirus-\(ncov\)](https://www.who.int/publications-detail/disease-commodity-package---novel-coronavirus-(ncov))

- The order of items matches the WHO Priority Medical Device list, and this ordering is important
- The prices match the WHO Catalogue price, where available; and if not detailed in the catalogue were estimated by through getting three quotes (each with a low-high range) and taking the average
- Since critical patients can be treated with a range of non-invasive and invasive ventilation machines, modelling is based on an assumption of how this is split by equipment with: 2/3 of critical patients forecast to require mechanical invasive ventilation; and 1/3 of critical patients forecast to require non-invasive ventilation, with the 50% of these using a CPAP device and the other 50% using a High Flow Nasal Cannula. Consumables and accessories assumptions related to these types of patient care are then based on these splits

Drugs usage assumptions are calculated in terms of a package of drugs that has enough therapeutics to cover 40 severe/critical patients with no breakdown of requirements for each patient by severity or how a group of 40 patients is composed in terms of age/gender/severity/co-morbidities. This packaged information including all quantities and cost was provided by the WHO OSL team.

User Dashboard Tab

Structure

The User Dashboard is structured in four sections from top-to-bottom:

- **Scenario inputs section:** This section includes inputs for a user to model –
 - Infections and Growth rate, i.e., select the scenario for modelling case load over time
 - Forecast period, i.e., select the window – within the advised constraints – for including in the total forecast
 - Testing strategy, i.e., select who is tested (suspected, mild, moderate, severe, and critical cases) and how many times for diagnosis and release

These inputs were kept separate from the Inputs tab to reflect the fact they are not country or context parameters and are instead determining the scenario to run.

- **Output figures:** This section visualizes key outputs for users, including cases over time, tests over time, admitted patients and bed occupancy over time, and procurement costs by category.
- **Summary tabular information:** This section details high-level outputs related to HCWs and other staff required per week and patient numbers and beds used per week. Users must note that this should not be used in place of specific HRH forecasting tools (e.g., HWFE¹¹) and that this information is displayed in order to explain bottom-up how the totals on PPE and biomedical equipment have been calculated.
- **Summary supply forecast:** This details the total number of each item forecast for the selected period and the corresponding cost for each line item.

Methodology and assumptions

Scenario inputs

Define infections & Growth rate:

Users can toggle between multiple methodologies for forecasting infections over time. Depending on user selection, different input cells or links to other input cells will appear to model infection growth using the selected methodology.

- **Exponential growth:** Exponential growth is an automated way to calculate the number of cases over time based on two elements (disease doubling times and clinical attack rates) informed by current trends shared by experts and academic groups. This was the only infection growth rate option in v1 of the ESFT, but with the addition of an SIR model (see below), users are advised not to use this option for modelling from v2 onwards.
 - *Doubling time:* the estimated number of days it takes for the number of cases to double. This will essentially serve as a basic way to model the speed at which the epidemic growth curve develops over time. There are five different presets for speeds of doubling time, as follows:

¹¹ <http://www.euro.who.int/en/health-topics/Health-systems/pages/strengthening-the-health-system-response-to-covid-19/surge-planning-tools/health-workforce-estimator-hwfe>

Doubling rate	# of days to double	Source
Very low	7.0	WHO 11 March AEM, control measures upper range
Low	5.0	WHO 11 March AEM
Medium	4.0	WHO 11 March AEM
Fast	3.2	WHO 11 March AEM
Very fast	2.3	WHO 11 March AEM, uncontrolled lower range

- *Clinical attack rate (CAR)*: the proportion of the population estimated to contract the disease and present with clinical symptoms. This will essentially serve as an upper limit to the total number of cases possible within a population. There are four presets for the CAR in the model, each of which were informed by unpublished country-level analyses produced by WHO and other academic groups:

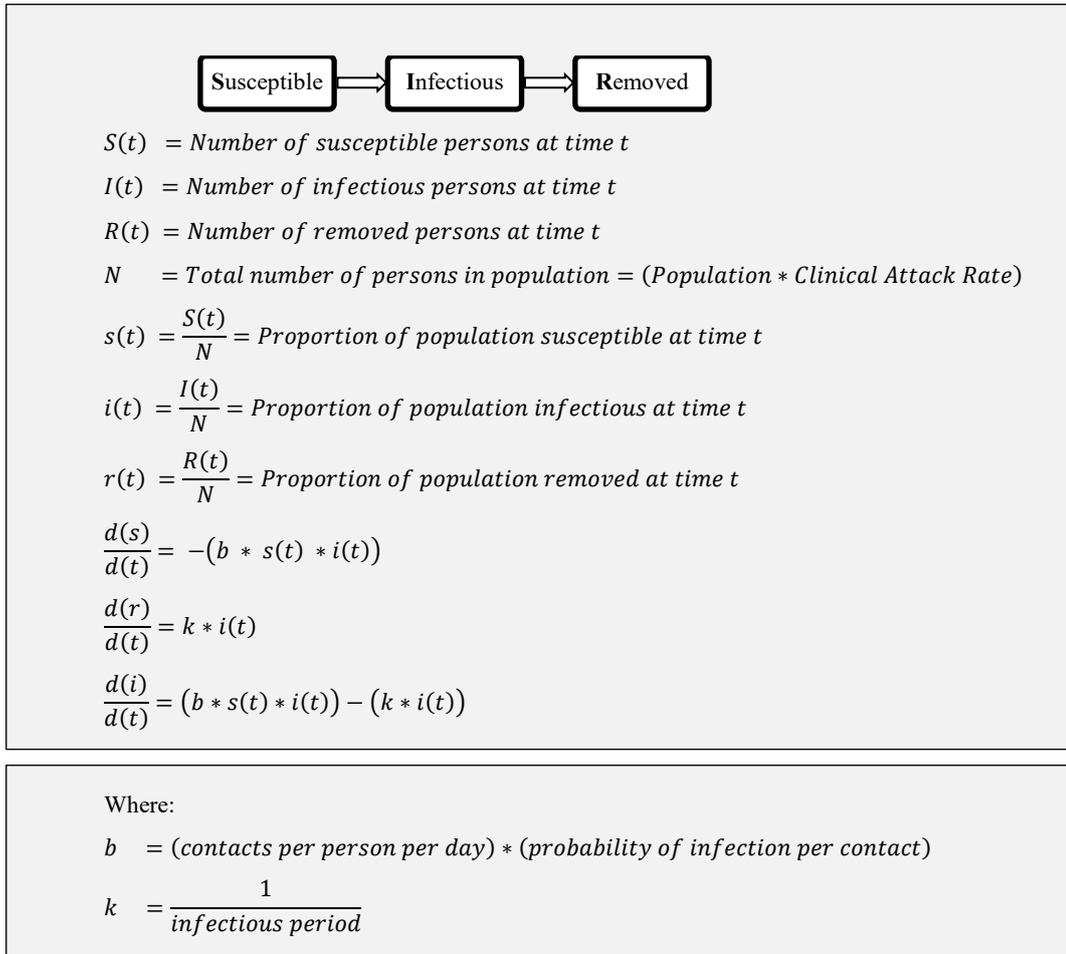
Clinical attack rate	% of population with clinical diagnosis	Source
Very low	5%	Based on China, low
Low	10%	Based on South Korea
Medium	20%	Based on Italy
Fast	30%	Based on Diamond Princess

- It is worth noting that WHO is currently investigating clinical attack rate values through rigorous research¹² – default values will evolve in the future as more information is available.
- Users can enter a manual doubling time and clinical attack rate.
- The cumulative cases in any given week of the forecast period are estimated through the cumulative cases at the start of the forecast period (X) and the specified doubling time (Y), capped at the maximum number of cases possible estimated by the population size multiplied by the clinical attack rate.

$$\text{Cumulative cases by time } t = X * 2^{\left(\frac{t}{Y}\right)}$$

- **SIR Model:** The Susceptible-Infectious-Removed (SIR) model is a basic compartmental model commonly used in infectious disease epidemiology. The population is divided into three compartments, Susceptible, Infectious, and Removed, and transmission parameters are specified to define the rate at which persons move between compartments. The SIR model here has a simple deterministic structure, with transmission parameters specified either by the reference values provided or those entered by the user. It is not fitted to reported COVID-19 case or death data. The model structure and system of equations is as follows:

¹² [https://www.who.int/publications-detail/the-first-few-x-\(ffx\)-cases-and-contact-investigation-protocol-for-2019-novel-coronavirus-\(2019-ncov\)-infection](https://www.who.int/publications-detail/the-first-few-x-(ffx)-cases-and-contact-investigation-protocol-for-2019-novel-coronavirus-(2019-ncov)-infection)



• Key parameter inputs include the following:

- *Infectious period*: the average number of days during which an infected person is likely to transmit the virus to susceptible persons. Modifications to this parameter may have a large impact on the forecasted epidemiologic curve. It is advisable to consult an infectious disease epidemiologist to appropriately set this parameter. The reference value provided is seven days.¹³
- *Current cumulative cases no longer infectious (Recovered or Dead Cases)*: the total number of cases no longer infectious is used to estimate the current number of active infectious cases in the SIR model by subtracting those no longer infectious from the total cumulative cases. If unknown, the cumulative case count one infectious period prior to today can be used. The reference value is an estimate of the number of cumulative cases one infectious period prior to the date of the forecast derived from the specified infectious period (X) and cumulative cases on the date of the forecast (Y), as well as assumed exponential growth in the days leading up to the date of the forecast with a doubling time of four days (Z):

$$\text{Cumulative cases no longer infectious} = 2^{\frac{\left(\frac{(\ln(Y)) * Z}{\ln(2)}\right) - X}{Z}}$$

- *Current contacts per person per day*: the average number of other people that one person encounters per day. Country-specific reference values are provided based on extrapolation from an international social mixing study. The original data was collected in the POLYMOD study conducted in eight countries, where a contact was operationally defined as either physical or nonphysical contact.¹⁴ Extrapolation to 152 countries was done through a study that modelled country-specific age-stratified contact matrices based on the POLYMOD data and country demographics, such as age structures.¹⁵ The reference value is specific to the country input based on collapsing the age-stratified contact matrices to a single average number of contacts per person per day for 152 countries. For other countries, the average for the income group is provided as the reference value. If a user is modelling a manual population size, the global average is provided.

¹³ Prem K, et al. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. *Lancet Public Health*. 2020 Mar 25. pii: S2468-2667(20)30073-6. doi: 10.1016/S2468-2667(20)30073-6. [Epub ahead of print]; and Woelfel R, et al. Clinical presentation and virological assessment of hospitalized cases of coronavirus disease 2019 in a travel-associated transmission cluster. *medRxiv*. 2020; (published online March 5.) (preprint). DOI: 10.1101/2020.03.05.20030502.

¹⁴ Mossong J, Hens N, Jit M, et al. Social contacts and mixing patterns relevant to the spread of infectious diseases. *PLoS Med*. 2008;5(3):e74. doi:10.1371/journal.pmed.0050074 (POLYMOD)

¹⁵ Prem K, Cook AR, Jit M. Projecting social contact matrices in 152 countries using contact surveys and demographic data. *PLoS Comput Biol*. 2017;13(9):e1005697. Published 2017 Sep 12. doi:10.1371/journal.pcbi.1005697

- *Probability of infection per contact*: the average likelihood or risk that a susceptible person becomes infected when contacting an infectious person. The reference value is calculated based on using 2.35 as the basic reproduction number¹⁶ as well as the infectious period (X) and contacts per person per day (Y) specified:

$$\text{Probability of infection per contact} = \frac{2.35}{X * Y}$$

- *Reproduction number*: the average number of secondary cases generated from a single infected case. For the initial stage of the SIR, the basic reproduction number is estimated to be 2.35.¹⁷ To use a different reproduction number, the transmission parameters can either be modified directly in the SIR Model Step 1 or a different reproduction number can be specified in the SIR Model Step 2 and 3.
- The transmission parameters are related via the following formula. Thus, specifying any three of the parameters will allow the fourth to be calculated.

$$\begin{aligned} & (\text{Infectious period}) \\ & * (\text{Contacts per person per day}) \\ & * (\text{Probability of infection per contact}) \\ & = \text{Reproduction Number} \end{aligned}$$

- Users can choose to alter SIR parameters over time for up to five different time-dependent periods or ‘stages’. Each stage is defined by its start date and either anticipated reproduction number or contacts per person per day. These are specified in the SIR Model Steps 2 and 3.
- After selecting input values for the transmission parameters, the SIR model details can be viewed in the ‘SIR Model Patient Calcs’ tab, although no additional input is needed here.
- **Manual entry:**
 - Users can model the infection growth rate entirely manually through selecting this option. If selected, they are guided to toggle to a specific tab for entering cumulative case load over time via a link.
 - Data validation on the input area ensures that users enter cumulative case load, rather than new cases per week.

Determine forecast period

Users are prompted, and constrained, to enter a maximum forecast period based on the total length of time until the COVID-19 has infected all members of the population that it is forecast to affect, as determined by the population size and clinical attack rate.

Users can enter a lag time of up to one week (for the time for shipments to arrive) to push the forecast period out one week. We recognize that the delay between ordering and item arrival is likely over one week, nevertheless this constraint was applied in order to mitigate the risk of forecasting very far out in the future, when there are so many unknowns regarding how infections will grow over time due to mitigation and suppression activities.

Testing strategy

There are two available testing strategy options including “All Suspected Cases” and “Targeted”. These are based on guidance from the WHO Laboratory testing strategy recommendations¹⁷.

- *All Suspected Cases*: this testing strategy assumes that tests will be administered to all presenting suspected cases. Based on guidance, the default assumption is that for every positive COVID-19 case detected there will be 10 negative tests, but this is an editable assumption.
- *Targeted*: Tests are only provided for the proportion of cases classified as severe and critical plus an additional user-defined buffer on top to allow testing of vulnerable at-risk populations. This buffer is also applied to the assumption about the number of negative tests for every positive COVID-19 test as described above.

Users can then decide how many tests to conduct for patients, by severity, for diagnosis and release.

Output figures

All output figures draw from the summary tabular information and summary supply forecast to display information in visual form for easier digestion.

Summary tabular information

This information pulls from the ‘Weekly Summary’ tab. See below for more information on how these values are calculated.

Summary supply forecast

This information pulls from the “Equipment List & Usage” tab and is calculated as explained above.

¹⁶ Kucharski AJ, Russell TW, Diamond C, et al. Early dynamics of transmission and control of COVID-19: a mathematical modelling study. *Lancet Infect Dis* 2020; published online March 11. [https://doi.org/10.1016/S1473-3099\(20\)30144-4](https://doi.org/10.1016/S1473-3099(20)30144-4)

¹⁷ https://apps.who.int/iris/bitstream/handle/10665/331509/WHO-COVID-19-lab_testing-2020.1-eng.pdf

Summary Tabs – Commodities by Week

The ‘Commodities by Week’ tab breaks out the total commodity need (as calculated and displayed on the ‘Equipment List & Usage’ tab) on a weekly basis for the duration of the forecast. This will enable more granular supply planning. The methodology for calculation is the same as the ‘Equipment List & Usage’ tab, it is simply a different way of displaying the tool outputs.

Summary Tabs – Weekly summary

Structure

The ‘Weekly summary’ tab calculates the number of patients by severity (mild, moderate, severe, and critical) that are ill/in care each week in both a capped and uncapped scenario. The uncapped scenario calculates cases by severity based on the infection growth. It also calculates the number of HCWs (for inpatients and screening/triage), Cleaners, Informal caregivers, Ambulance Personnel, Biomedical Engineers, and Lab Staff who are in operation each week and who would be required if availability were uncapped. The appropriate values (dependent on the forecast period entered) in ‘User Dashboard’ are selected from columns BF and BH to flow through to the ‘Equipment List & Usage’ tab for supply quantification. The tab is locked to users and are intermediate calculation tabs.

Methodology

Cases

Total uncapped new cases presenting each week are pulled from the ‘Patient calcs’ tab. Sick patients per week are calculated based on the delta between the new cases and those that recover in that week. Recovered (or dead) patients are calculated by shifting the new cases by the number of weeks of illness as per inputs, differentiated by patient severity.

Total capped cases that are admitted and in care each week are calculated using the following logic:

- For each week, the number of sick patients in care is calculated as up to the cap based on the ‘Inputs’, e.g., the maximum number of severe patients in care is calculated as the maximum number of severe beds as per the ‘Inputs’ tab.
- For each week, the number of admitted patients is either a) the number of new cases presenting that week (if caps have not been reached) or b) back-calculated based on subtracting the number of patients that were removed (due to recovery or dying) from care from the total number of sick patients in care that week.

Diagnostics

Diagnostic tests are calculated based on the inputs on testing strategy from the ‘User Dashboard’ tab multiplied by the relevant case/patient numbers.

Health workforce and staff

Health care worker and other staff numbers are calculated by multiplying the staff ratios by the patient numbers as per above. Unconstrained HCW numbers are also calculated to provide insight into how many HCWs would be required to maintain ideal HCW/patient ratios.

Outputs

The two key columns for feeding the rest of the model are column BF and BH. Column BF calculates, using a SUMIFS formula, the total number of each line item over the forecasting period, i.e., from the current time point (plus 1 week if allowing a lag for delivery) to the end forecasting week. These values are used to calculate equipment needs where equipment is based on occupancy of beds or presence of staff overtime (e.g., consumables). Column BH calculates, using an array MAX formula, the maximum volume for each row within the forecasting period (as before). For exponential growth case scenarios, this max will usually occur at the end of the period since cases double over time until the CAR is reached. However, for SIR or manual entry case growth, the maximum bed occupancy and staff presence could occur in any given week, which is why an array formula is used. These values are used to calculate equipment needs where equipment is based on maximum needs required (e.g., biomedical equipment positioned at the ends of beds).

Patient Calculations Section

Structure and methodology

The top of this tab calculates in vertical columns the breakdown of cases, by severity, for unconstrained cases (i.e., not factoring in bed capping). Details on information from left to right columns:

- Cumulative total cases column is fed by the selected case estimation method (e.g., exponential growth, SIR model, or manual) and specified transmission parameters (e.g. growth rate, infectious period, etc.). This is then broken down into case severity based on the inputs on severity breakdown
- Removed cases are calculated by shifting the total cases down for the number of weeks corresponding to the duration of illness by case severity

- Quarantines and admissions (no capping) calculates the number of new cases per week by subtracting the cumulative cases week by week to get the new cases
- Suspected cases that test negative are calculated based on the input of suspected cases to positive cases and the cumulative
- These values then feed into the ‘Weekly summary’ tab to all the uncapped rows, where additional calculations (described above) are completed to calculate the capped scenario

Further down, the tab has a section for manual patient calc inputs, which is hyperlinked from the ‘User Dashboard’ tab if being used.

Below this are automated calculations that feed in from the relevant other calculations tab to populate values for the SIR model and Exponential growth based on what is being used.

SIR Model Patient calculations

This sheet provides the daily SIR-model calculations of Susceptible, Infectious, and Removed populations based on the specified population size, current cases, and transmission parameters. The calculations are described above.

Reference Data

HCW, Staff, Beds Summary

This tab consolidates information from the ‘WHO GHO Data’ and ‘WB Beds’ and ‘UNDP Population data’ to give tabular information showing country name, code, WHO region, income group, and total numbers of doctors, nurses and lab staff.

WHO GHO Data

This tab consolidates cleaned data sets from the WHO Global Health Observatory for nurses, midwives, lab staff and doctors¹⁸. WHO GHO data is reported in absolute values of cadres for the latest reported year. We applied the five-year average growth rate for each country to manipulate the reported values to a 2020 figure.

As described above, we plugged any gaps where values were not reported by taking the income group average for each non-reported country to reduce the risk of underestimating in the demand forecast.

WB Beds

This tab details the raw data downloaded from the World Bank¹⁹ for the number hospital beds per 1000 people by country per year.

As described above, we plugged any gaps where values were not reported by taking the income group average for each non-reported country to reduce the risk of underestimating in the demand forecast.

UNDP Population data

This tab details raw data from the World Bank²⁰ on country population totals for 2015, 2020 and population growth between these two timepoints.

Back calculations

This tab is a large compilation of all the back calculations used as intermediate calculations in the tool.

Staff & Infrastructure Assumptions

Bed Capping Calculations

- This section simply pulls through the World Bank data from the ‘WB Beds tab’ for the country that is selected in the ‘Inputs’ tab and the population data from the ‘UNDP Population Data’ tab and multiplies together to give the reference value for total number of beds in county.
- If the user is running a manual scenario, the global average beds per capita is applied to the manually entered population size.

Country health worker calculations

- *Input prompts from datasets:* This section pulls through the number of doctors, nurses, and laboratory staff from the ‘HCW + Staff Summary’ tab for the user selected country.

¹⁸ <https://apps.who.int/gho/data/node.main.HWFGRP?lang=en>

¹⁹ <https://databank.worldbank.org/home.aspx>

²⁰ <https://databank.worldbank.org/home.aspx>

- *Output proposed caps based on user inputs:* It then calculates the reference absolute values of HCW/staff across settings of care based on the user inputs for the % split across settings.
- *Calculating weight average HCW per inpatient bed:* This calculates the % of all severe plus critical cases and critical vs. severe to feed into calculations on HCW ratios per bed.
- *Calculating split of HCWs for inpatients vs. outpatient for HCWs working on COVID-19:* On the ‘Inputs’ tab, users are required to enter a % estimate to split out HCWs into a) non-COVID-19 work, b) COVID-19 inpatient care, and c) COVID-19 screening/triage in order to feed into PPE calculations as caps on HCW availability. The prompts and reference values for users are calculated here by comparing the HCWs required per inpatient vs. for screening/triage, which depends on:
 - Case severity breakdown – i.e., what is the probability that each new case requires inpatient care vs. just screening and triage
 - HCW ratios per bed – i.e., for inpatients, how many HCWs are required per day and thus what is the inpatient: HCW ratio
 - HCW screening rate – i.e., for screening/triage, how many patients can a single HCW see per day and thus what is the “outpatient” (refers to screening/triage): HCW ratio
 - The inpatient vs. “outpatient” HCW ratios are compared to give the % of total HCWs required for inpatient vs. “outpatient” care

Diagnostic calculations

Equipment inputs

- *Useable quantity/kit (minus wastage):* This calculates the “useable” extractions in a lab extraction kit and RT-PCR tests in a RT-PCR kit that considers wastage (user input on Inputs tab)
- *Mid-calculations, based on model calculations:* This calculates the number of tests conducted (both manual tests separately as well as all testing modalities), the number of hospital facilities in-use, and the number of “facility weeks” in operation throughout the forecasting period. These midpoint calculations feed into the Equipment Quantification section below, which calculates the lab testing and sample transport needs over the forecast period

Equipment quantification

This section calculates the supply forecast for diagnostic equipment that is calculated on a per facility, per test, or per week basis – dependent on the relevant inputs in the ‘Inputs’ tab and the relative variables (number of facilities, number of tests, and number of weeks of forecast) respectively.

Oxygen Calculations

This section calculates the maximum O2 flow rate at maximum occupancy through pulling in the total number of severe beds and critical beds occupied during the forecast period, capped by the total available in the country/setting. It multiplies these bed numbers through by the entered input on LPM per severe and critical patients to give a total.

Patient Calculations

Inputs: This section provides reference values and inputs for the doubling rate options (described above) and clinical attack rate options (described above).

Epi curve calculations: These series of calculations are used when running an ‘Exponential growth’ infection growth scenario. These calculations will help pinpoint the current point of the outbreak on an exponential curve defined by the specified doubling time. This can then be used to calculate how many weeks remain until the clinical attack rate population is reached to define a maximum forecast period.

Scenario running: These values take inputs from ‘User Dashboard’ to use as source material for indexing in the ‘SUMMARY TABS ->’ to populate the relevant week columns.

Diagnostics maximum testing capacity

This section calculates the maximum number of diagnostics tests that can be conducted per day in a given country/setting based on the user inputs for the number of active platforms and shift patterns, combined with default assumptions on the throughput per shift.

Blank sheets

The tool contains four blank and unlocked worksheets that users can manipulate and use during the forecasting period

Hidden tabs

Lists

This tab simply details lists for any data validation criteria, alongside providing details on values selected in drop downs through index matching.

Staffing from HRH tool

This tab is the reference material for calculating HCW/patient ratios for inpatient care and screening/triage. It is taken from the WHO Health Workforce Estimator tool (HWFE)²¹ as of 14th April 2020.

Diagnostics module

This tab includes detailed back calculations for calculating the total available testing capacity for COVID-19. The tab contains the reference values on machine placements by country (see Labs and Testing section of Inputs tab for more information on this table). It also contains the calculations for allocating test kits for procurement according to available capacity and the additional capacity that would be added if users choose to input new device placements on the Inputs tab.

Daily contacts by Country

This tab provides reference values for the estimated number of contacts each person in each country has based on Prem et al., 2017²², discussed in the SIR-model methodology section above, which is used as a default input to the SIR model.

WHO continues to monitor the situation closely for any changes that may affect this interim guidance. Should any factors change, WHO will issue a further update. Otherwise, this interim guidance document will expire 2 years after the date of publication.

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WHO reference number: [WHO/2019-nCoV/Tools/Essential_forecasting/Overview/2020.1](#)

²¹ <http://www.euro.who.int/en/health-topics/Health-systems/pages/strengthening-the-health-system-response-to-covid-19/surge-planning-tools/health-workforce-estimator-hwfe>

²² Prem K, Cook AR, Jit M. Projecting social contact matrices in 152 countries using contact surveys and demographic data. PLoS Comput Biol. 2017;13(9):e1005697. Published 2017 Sep 12. doi:10.1371/journal.pcbi.1005697