COVID-19

COVID-19 Models:

Forecasting the Pandemic's Spread and Planning for Recovery

(Updated September 10, 2020)

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With our evolving understanding of the details of COVID-19 infection and transmission, the impact of social distancing measures and other factors, hospitals and health systems face complex forecasting challenges.

A large number of models have been developed by health care systems, academic institutions, consulting firms and others to help forecast COVID-19 cases and deaths, medical supply needs, including ventilators, hospital beds and intensive care unit (ICU) beds, timing of patient surges and more.

We recognize that all forecasting is imperfect and that models often change as data are revised to reflect evolving conditions in the population. The American Hospital Association (AHA) offers this resource in response to members' interest in tools and resources that can help them make decisions that are consistent with their organizations' values and community needs.

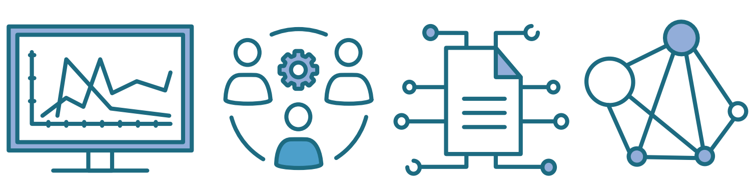
The **CASE PROJECTION AND CAPACITY PLANNING** models all are predicated on some assumptions about the current status of the disease, how quickly it spreads (e.g., doubles), and/or the degree of containment efforts being deployed. These assumptions drive the rise, peak and decline in "the curve" — the number of COVID-19 cases, deaths or resources needed. The simpler models apply the user's inputs on the local population and current status of COVID-19. The more complex models allow the user to alter other parameters (e.g., changes in social distancing) that influence the curve. Some models match projected cases to existing capacity to estimate when and where a caseload surge will exceed capacity.

The **COMMUNITY VULNERABILITY MAPS** use social and economic population variables, such as density, travel distances to health care, underlying chronic illnesses and economic status to highlight communities that are most at risk for contracting and/or succumbing to the disease.

The **CASE MAPPING AND PROJECTION TOOLS** provide a quick visual depiction of disease incidence at the national, state or county levels.

The newly added **RECOVERY CALCULATORS** help estimate how long it will take to complete backlogs of postponed procedures, and model estimated critical care capacities based on given inputs at baseline.

The following list of resources was updated Sept. 10 and is not exhaustive. It will continue to be updated periodically as additional models are assessed. These resources are classified into categories based on the extent of their modeling capabilities and how they can be used.



Please note that the tools listed do not necessarily reflect the views of the AHA, nor do they constitute advice from the AHA. Rather, they are meant to assist hospitals and health systems in making decisions for their own organizations.

Harvard University — *Regional Hospital Capacity Calculator*

This model was developed by researchers at the Harvard Global Health Institute (HGHI) and the Harvard T.H. Chan School of Public Health, and was launched in collaboration with ProPublica, and in sync with news reports in The New York Times and "CBS Morning News." The model provides projections for the U.S. and for each Hospital Referral Region (HRR).

ADDITIONAL DETAILS

- **Data and assumption sources:** The model combines data on hospital beds and population with estimates from recent research on estimated infection rates, proportion of people hospitalized (general medical-surgical and ICU), average lengths of stay (LOS), increased risk for people older than 65 and transmission rate. The data used to produce the estimates are available and can be downloaded from the HGHI site. It is not clear when the data were last updated.
- **Estimation level:** HRR.
- **Social distancing mandates/scenarios:** None.
- **Degree of complexity:** Easy. Users can click on a specific HRR on the map and see results using the default assumptions. Users also can explore the data and see results in bar charts here. [Note: Scroll down to see the bar charts.]
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** Yes.
- **Output:** National heat maps show HRRs and the percentage of occupancy levels under three different national infection rates (20%, 40% and 60%) and within three time periods (6, 12 and 18 months), as well as bar charts showing the same information for the chosen HRR.
- **Methodology**: Methodology and assumptions documentation.

Qventus — *Localized COVID-19 Model and Scenario Planner*

The Qventus model provides localized projections based on the latest local estimates and research on COVID-19. The estimates are projected using a modified Susceptible-Exposed-Infectious-Recovered (SEIR) model that starts with local case counts and resource estimates. The model's parameters are populated automatically with assumptions specific to the HRR of the selected hospital(s). Qventus continually updates the estimates and assumptions based on actual disease progression.

ADDITIONAL DETAILS

- **Data and assumption sources:** Default model assumptions, such as current COVID-19 census, growth rate, percentage of infections reported, average recovery time and hospitalization rates, come from multiple sources, including current county case counts, recently published research, Healthcare Cost and Utilization Project and Qventus clients.
- **Estimation level:** HRR.
- **Social distancing mandates/scenarios:** Yes. They take into account the following social distancing effects with anticipated dates: pre-COVID-19, no policy, minimal, moderate, significant, severe.

ADDITIONAL DETAILS

- **Degree of complexity:** Easy. User inputs hospital name and receives HRR results using the default assumptions or the user's own assumptions. Users also can download and share the output.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** Users can alter model scenarios (e.g., social distancing, improved LOS flow, bed capacity, staffing), market conditions (e.g., population and market share), hospital assumptions (e.g., ICU capacity and current COVID-19 census) and COVID-19 assumptions (e.g., doubling time and fatality rate).
- **Output:** Expected next seven-day admissions requiring med-surg only, ICU or ventilator and days until resource capacity is reached; expected total deaths over the next 45 days, projected cumulative med-surg and ICU occupancy, and ventilator and personal protective equipment (PPE) utilization.
- **Methodology:** Methodology and assumptions documentation. Description of SEIR modeling: https://www.idmod.org/docs/hiv/model-seir.html.

Penn Medicine — *CHIME: The COVID-19 Hospital Impact Model for Epidemics*

This model allows hospitals to enter information about their population and modify assumptions about the spread and behavior of COVID-19. It then runs a standard Susceptible-Infected-Recovered (SIR) model to project the number of new COVID-19 hospital admissions each day, along with the hospital census of COVID-19 patients. These projections then can be used to create best- and worst-case scenarios to assist with capacity planning. Penn Medicine is open-sourcing CHIME and making it available to the health care community. An extension to the model is being built (BayesCHIME) to extend this model into predicting infections after the peak, which provides capacity planners with more insight.

ADDITIONAL DETAILS

- **Data and assumption sources:** The discrete-time SIR model has user inputs for population, the hospital's market share, current COVID-19 hospitalizations, doubling time, severity and social distancing. It employs a combination of local estimates and estimates from other locations (e.g., Wuhan, China; South Korea; Italy), informed estimates based on logical reasoning.
- **Estimation level:** Individual hospital or health care system.
- **Social distancing mandates/scenarios:** Yes. Provides option to add date of social distancing measures' effect and percentage of reduction in social contact moving forward.
- **Degree of complexity:** User interface with tutorial and documentation.
- **Software platform/language:** Web-based and Python.
- **Ability to change assumptions and run scenarios:** Yes.
- **Output:** Projected new COVID-19 admissions per day (e.g., hospitalized, ICU, ventilator) and projected total COVID-19 patients per day for the same three cohorts. Projections for SIR patients.
- **Methodology:** SIR model documentation and Python code. BayesCHIME Python script: https://github.com/pennsignals/chime_sims/blob/master/README.md.

Health Catalyst — *Capacity Planning Tool*

This tool offers two models: (1) a model that builds on Penn Medicine's model, and (2) an empirical model based on actual county-level data and dynamic infection spread rates. Users have the ability to run multiple scenarios, store the scenarios on their local desktops and then upload them again for later use. Additional features include predicted impacts of scenarios on hospital capacity (e.g., beds and ventilators).

ADDITIONAL DETAILS

- **Data and assumption sources:** Penn Medicine's discrete-time SIR model. User inputs for population, market share, current COVID-19 hospitalizations, hospital capacity, doubling time, severity and social distancing.
- **Estimation level:** Individual hospital or health care system or state and county level.
- **Social distancing mandates/scenarios:** Yes. User can select a social distancing start date and the degree of reduction in social contact going forward.
- **Degree of complexity:** User interface with tutorial and documentation.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** Yes.
- **Output:** Projected new COVID-19 admissions per day (e.g., hospitalized, ICU, ventilated) and projected total COVID-19 patients per day for the same three cohorts. Projections for SIR and bed capacity (e.g., total beds, ICU beds, ventilators).
- **Methodology:** Statistical model documentation and application guidance.

UW-IHME — *COVID-19 Forecasting Tool*

The University of Washington's Institute for Health Metrics and Evaluation (IHME) forecasting tool provides state-by-state information on anticipated number of beds needed, ICU beds needed and deaths related to COVID-19. Projections assume social distancing until infections are minimized and containment is implemented. The tool does not permit hospital-level inputs and alternate scenarios.

ADDITIONAL DETAILS

- **Data and assumption sources:** Data on confirmed COVID-19 deaths by day from World Health Organization websites and local and national governments; data on hospital capacity and utilization for U.S. states from the American Hospital Association (AHA); and observed COVID-19 utilization data from select locations (e.g., Italy, China, Korea and the U.S). Model forecasts peak death and resource usage dates, and daily deaths and hospital utilization (e.g., beds, ICU beds, ventilators) against capacity by state and for the U.S. over the next four months, assuming three social distancing scenarios ("current projection", "mandates easing", and "universal masks") that are described in more detail here.
- **Estimation level:** Individual states and the U.S.
- **Social distancing mandates/scenarios:** Yes. They take into account typical mobility and when social distancing mandates ease; mask use represents the percentage of people wearing masks in public.
- **Degree of complexity:** No user inputs, easy to comprehend.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** No.
- **Output:** Graphs showing peak death and resource utilization dates, daily total bed and ventilator needs and shortages, and projected deaths.
- **Methodology:** Statistical models (e.g., nonlinear mixed-effects model) documentation and model FAQs.

RAND Corporation — [*Critical Care Surge Response Tools*]

In this report, the authors present a list of strategies for creating critical care surge capacity and estimating the number of patients accommodated, given the number of available critical care doctors and nurses, respiratory therapists, ventilators and hospital beds. They also document the development of a user-friendly, Microsoft Excel-based tool that allows decision-makers at all levels — hospitals, health care systems, states, regions — to estimate current critical care capacity and rapidly explore strategies for increasing it.

ADDITIONAL DETAILS

- **Data and assumption sources:** Formulas driven by user inputs — staff ratios, staff levels, additional personnel resources and patient capacity; model uses AHA data, American Medical Association data, and other data on critical care space, staff and supplies (e.g., ventilators, PPE).
- **Estimation level:** Individual hospital, health care system, regional or state levels.
- **Social distancing mandates/scenarios:** No.
- **Degree of complexity:** Clear descriptions of required inputs.
- **Software platform/language:** Excel.
- **Ability to change assumptions and run scenarios:** Yes.
- **Output:** Total number of patients who can be cared for per shift by staff and resource type.
- **Methodology:** Limited documentation.

NEW Hospital IQ – *COVID-19 Forecast*

This web-based model provides state- and county-level data to help hospitals plan for increased patient demand. It provides estimates in weekly confirmed cases and infections to date, along with peak med-surg beds, ICUs, and ventilators. This model is continually updated.

ADDITIONAL DETAILS

- **Data and assumption sources:** State and county population U.S. Census data, COVID-19 trends from Johns Hopkins University, COVID Tracking Project, Centers for Disease Control and Prevention; statistics from Definitive Healthcare on county med-surg and ICU capacity, and state-by-state forecasts from UW-IHME data.
- **Estimation level:** State or county level.
- **Social distancing mandates/scenarios:** Yes. Forecast based on IHME model which takes into consideration the social distancing mandates in each state.
- **Degree of complexity:** No user inputs, easy to comprehend.
- **Doftware platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** No.
- **Output:** User interface provides weekly change in newly confirmed cases, doubling time, percentage infected to date, confirmed cases and deaths to date, med-surgbeds, ICU beds, and ventilators at peak (also includes trends over time for these variables).
- **Methodology:** County-level forecasts are prorated from state forecasts based on the greater of the county-to-state population ratio and county-to-state COVID-19-related death ratio.

NEW Columbia Mailman School of Public Health – *Estimated Daily COVID-19 Cases and Available Hospital Critical Care Beds*

This meta-population SEIR model simulates the transmission of COVID-19 among 3,142 U.S. counties. The graphs allow users to see daily projections of COVID-19 infections and available hospital critical care beds looking forward for 42 days, in each state and county. A companion risk-mapping tool presents forecasts of future COVID-19 case counts and trends along with hospital resource demand.

ADDITIONAL DETAILS

- **Data and assumption sources:** (1) 2020 Centers for Medicare & Medicaid Services (CMS), Healthcare Cost Report Information System data file, subsystem for the Hospital Cost Report; (2) the 2018 AHA Annual Survey; (3) the 2020 U.S. Department of Health & Human Services Health Resources and Services Administration, Area Health Resources Files; and (4) the 2017-2019 CMS Medicare Provider of Services file, Medicare Cost Report, Hospital Compare files.
- **Estimation level:** State or county level.
- **Social distancing mandates/scenarios:** Yes. User can choose the degree of change in social contact (see assumptions and scenarios below).
- **Degree of complexity:** No user inputs, easy to comprehend.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** User can choose from four options for the COVID-19 reproductive number (R), reflecting change in social contact and seasonal effect: no change in R throughout the projection, a one-time 5% increase in R, a 5% increase in Weeks 1 and 2 and then R is set to 1 for the remainder of the projection, and a 10% decrease in R each week.
- **Output:** User interface provides a side-by-side comparison of two out of five different variables at a time: daily confirmed cases, daily newly infected cases (documented and undocumented), available hospital critical care beds under three levels of surge response (low, medium, high intensity) at state and/or county level, people 65 and older, and Medicare patients with chronic conditions.
- **Methodology:** Methodology shared here and here.

COMMUNITY VULNERABILITY MAPS

Jvion — *COVID-19 Community Vulnerability Map*

Clinical artificial intelligence company Jvion launched this public-facing tool, built on Microsoft Azure maps. It enables health care providers and communities battling the COVID-19 pandemic to identify the social determinants of health that put populations at greater risk, informing community planning and resource allocation to proactively mitigate the risk to vulnerable populations. The interactive map identifies populations down to the census block level that are at risk for severe outcomes upon contracting a virus like COVID-19. It is not clear when the data were last updated.

Conduent — *Covid-19 Vulnerability Index Map*

Conduent Healthy Communities Institute's tool lets users track potential severe illness burden due to COVID-19 by county through the COVID-19 Vulnerability Index. This index is based on trends in reported COVID-19 cases and deaths, clinical risk factors, and social and economic determinants. Counties are given an index value from 1 (low vulnerability) to 10 (high vulnerability). A county with a high vulnerability score can be described as a location where a higher percentage of COVID-19 cases would result in severe outcomes, such as hospitalization or death, as compared to a county with a low vulnerability score. The COVID-19 Vulnerability Index map is continually updated based on Conduent Data and Analytic Innovations. A second map tracks at-risk populations at the county level through the SocioNeeds Index (SNI). SNI is a measure of socio-economic need that is correlated by poor health outcomes. Counties are given an index value of 0 (low need) to 100 (high need). It is based on the U.S. Census Bureau's American Community Survey from the most recent measurement period, 2014-2018.

NEW STAT – *COVID-19 Preparedness Scores*

With the partnership of Applied XL and the Center for Rural Innovation, STAT produced a dashboard model that predicts the preparedness of counties for a COVID-19 outbreak based on five variables: physical capacity (number of licensed hospital beds), human resources (number of critical care staff), percentage of older population (65 and older), social vulnerability index score (CDC rank measuring resiliency to natural disasters and disease outbreaks), and ICU bed shortage data from UW-IHME to assess the severity of the pandemic at a given time. The preparedness score is an unweighted average of the above variables and is scaled from 1 to 100. Preparedness of a county is categorized as follows: very low (less than 20), low (20-40), medium (40-60), high (60-80), and very high (>80). This model is based on the IHME model and data from the following sources: the Center on Rural Innovation, National Plan and Provider Enumeration System, American Community Survey and the CDC.

CASE MAPPING AND PROJECTION TOOLS

AHA — *COVID-19 Bed Occupancy Projection Tool and People Per Hospital Bed by Region Map*

The AHA developed these dashboards using data from its proprietary AHA Annual Survey, population estimates from the Census Bureau and case projections from the University of Washington's Institute for IHME COVID-19 forecasting tool. The IHME projections are updated regularly and take into account recent available information on social-distancing policies across states.

- **The COVID-19 Bed Occupancy Projection Tool** shows the all-bed and ICU-bed capacity by state, and compares that capacity to the IHME case projections. The user can select a future date and the percentage of hospital or ICU beds already occupied by non-COVID patients to assess when the projected need will exceed bed capacity for both COVID and non-COVID patients.

- **The People Per Hospital Bed by Region Map** shows population per bed as a measure of capacity for all adult beds and for adult ICU beds. The maps can be viewed at the state, HRR or Hospital Service Area level and can be filtered by population age groups, poverty rates and uninsured rates.

Oliver Wyman Consulting — [Oliver Wyman COVID-19 Pandemic Navigator]

This scenario generator from Oliver Wyman predicts the growth and peak of COVID-19 cases and mortality in the U.S. at the county level, based on the effectiveness of and time to implement containment measures. The tool allows for some user input and scenario modeling.

Dalla Lana School of Public Health, University of Toronto — [COVID-19 Growth Model]

The goal of this model is to provide insight into the changing nature of case findings and epidemic growth. The tool allows for user input and scenario modeling.

COVID Act Now — [Hospital Overload Projections for State/County Level]

The U.S. Intervention Model is a data platform that projects COVID-19 infections, hospitalizations and deaths across the U.S., as well as how public health interventions contain the spread of COVID-19. The model uses five key risk indicators to determine risk levels by state and county. It helps decision-makers understand when and how COVID-19 will affect their communities so that they can make better decisions that save lives.

NEW Dartmouth Atlas Project – [Mapping COVID-19]

The maps produced by Dartmouth use county-level data from The New York Times and aggregates county case and death rates to the 306 HRRs. These provide population-based COVID-19 cases, reported deaths and average growth rates over the previous week and are updated daily.

ADDITIONAL DETAILS

- **Data and assumption sources:** The New York Times COVID-19 county=level case counts and death rates, hospital capacity data are from Harvard Global Health Institute, MABLE datafile from Missouri Census Data Center (crosswalk between U.S. county and HRRs)
- **Estimation level:** HRR.
- **Social distancing mandates/scenarios:** No.
- **Degree of complexity:** User interface with tutorial and documentation.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** Yes.
- **Output:** For each HRR and for any date from March 1, 2020. to the current date, maps show the number of COVID-19 cases per 100,000 population, the average daily growth rate for the past seven days, the total number of new cases per 100,000 population over the past 14 days, the number of COVID-19 deaths per 100,000 population, and the HRR's rank (across all HRRs) in terms of these four measures.
- **Methodology:** Methods and limitations shared here.

RECOVERY CALCULATORS

NEW iQUEUE — *Elective Surgery Backlog Recovery Calculator*

This recovery calculator estimates how long a health care organization needs to complete electives that were postponed during COVID-19. The analysis is based on the size of backlog during the pandemic and recovery strategies hospitals can undertake post-pandemic (e.g., increasing volumes and/or extending operating hours).

ADDITIONAL DETAILS

- **Data and assumption sources:** Formulas are driven by baseline monthly cases pre- and during COVID-19, patient capacity, surge volume and utilization.
- **Estimation level:** Individual hospital, health care system, regional or state level.
- **Social distancing mandates/scenarios:** No.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** Yes, an option to model the second wave and change scenarios based on date of reopening.
- **Output:** Total backlog of cases, estimated additional cases to take per month and total length to recover backlog.
- **Methodology:** Limited documentation. [Note: Scroll down the page.]

NEW iQUEUE — *Infusion COVID-19 Volume Recovery Calculator*

This recovery calculator estimates how long your organization's infusion center needs to complete deferred patients during the COVID-19 crisis. The analysis is based on recovery strategies that hospitals can undertake post-pandemic (e.g., increasing volumes and/or extending operating hours).

ADDITIONAL DETAILS

- **Data and assumption sources:** Data are based on hospital estimates of typical weekly volumes prior to COVID-19, weekly volumes during the pandemic, timeline parameters, percentage of patients deferred and additional volumes, equipment and additional hours that can be added to accommodate a COVID-19 surge.
- **Estimation level:** Individual hospital or health system level.
- **Social distancing mandates/scenarios:** No.
- **Software platform/language:** Web-based.
- **Ability to change assumptions and run scenarios:** Yes. Shelter-in-place dates can be entered.
- **Output:** Size of backlog during COVID-19, time needed to recover and recovery speed.
- **Methodology:** Limited documentation. [Note: Scroll down the page.]