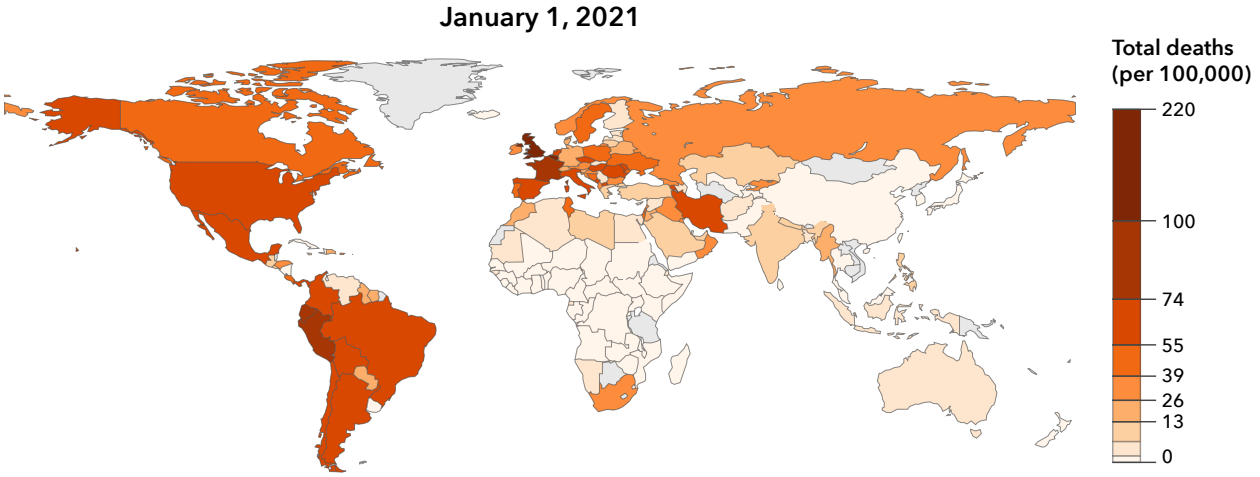
Projecting the Trajectory of the COVID-19 Pandemic

Utilizing the most up-to-date reported data, the COVID-19 projections published by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington are designed as a planning tool for decision makers to prepare for likely trajectories of the pandemic over the next 4 months. By modeling which locations are likely to experience continued growth or resurgence in COVID-19 cases, IHME's projections help to (i) reinforce public health messaging on the importance of mask use, (ii) estimate hospital resource needs, & (iii) highlight when social distancing mandates might be best timed to prevent exponential growth.



What measures are included?

- Projections 4-months into the future for each of the following indicators:
  - Daily deaths
  - Total deaths
  - Hospital resource use for COVID-19 patients (including hospital beds, ICU beds, & ventilators)
  - Mobility
  - Testing
  - Confirmed and estimated infections
- Historical timelines for each of these indicators, provided in both raw (reported) and smoothed formats.

What locations are included?

- National projections for all countries*
- State-level/provincial-level projections for select countries
- Global and regional aggregates based on the World Bank regions

*Countries with no or few reported COVID-19 deaths are omitted

Three Policy Relevant Scenarios

1 **MANDATES EASING**
Mask use continues at current rates, mandates continue to ease and are never reimposed

2 **CURRENT PROJECTION**
Mask use continues at observed rates, mandates reimposed at 8 deaths/day/million people

3 **UNIVERSAL MASKS**
Mask use rises to 95% within 7 days, mandates reimposed at 8 deaths/day/million people

IHME's COVID-19 Three-Stage Modeling Strategy

Model Stage 1: Fitting trends in deaths

A novel Random-Knot Combination Spline (RKCS) process is used to fit the curve of reported COVID-19 deaths, utilizing reported cases (and hospitalizations where data is available) as a leading indicator of deaths. RKCS models from previous week are combined in a weighted 7-day moving average. This process is used to overcome biases in reporting (such as differential reporting rates on weekends) to more closely estimate the true, underlying COVID-19 mortality trends. From this stage, short-term predictions (8-days) of age-specific deaths, by location, are produced. For an estimated historical time trend of infections, the death pattern produced by the RKCS process is multiplied by the infection-fatality ratio (IFR).

Infection Fatality Rate (IFR) by Age

Accounting for the relative risk of death by 5-year age-groups is a key part of the IHME model, as IFR is significantly lower in younger age groups.

Model Stage 2: Transmission modeling

With the short-term projections from the RKCS model, a random distribution of 0-8 days are passed through the transmission model with the following dynamic SEIIR framework:

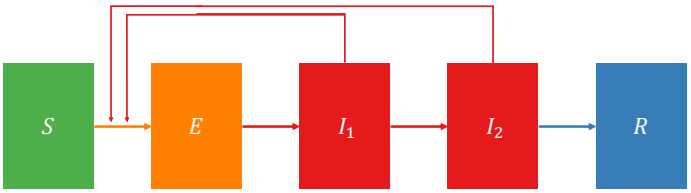
SUSCEPTIBLE (S): A person who has never been infected.

EXPOSED (E): A susceptible person who has been in contact with an infected person.

INFECTED (I_1): Not yet infectious, as incubation period is assumed to be 3 days.

INFECTIOUS (I_2): Infected person now infectious; infectious period is assumed to be 11 day.

REMOVED (R): Through recovery or death; no longer able to be infected.



Mask Use

Through a meta-analysis of more than 20 studies, whether cloth or medical grade, mask have been proven to reduce the risk of respiratory illness like COVID-19 by one third or more.

Model Stage 3: Hospital Resource Need

Utilizing the estimated number of infections and deaths from the SEIIR model, estimates of hospital resource use (ex. hospital & ICU bed use) are projected via microsimulations, assuming that those who don't visit the ICU are released after 8 days and those who do visit an ICU have a hospital stay of 20 days, the middle 13 being in an ICU.

Data Sources

Data from local & national governments, hospital networks, the WHO, & others are used, including:

- **Daily death numbers due to COVID-19:** Johns Hopkins University, supplemented with additional dataset, with some data processing accounting for inconsistent reporting practices (ex. delayed reporting of weekend deaths) or excess mortality where weekly vital registration data is available.
- **Testing:** Our World in Data, COVID Tracking Project, & government websites.
- **Mandates:** both official and open sources.
- **Mobility:** Facebook Data for Good, Google, Safegraph, & Descartes Labs.
- **Mask use:** Facebook & Premise

Drivers of Transmission – Model Covariates

Used to help overcome missing or incomplete data & contextualize the model to each location:

- **Mobility:** measured by smartphone apps, % reduction in mobility from January 2020 as a proxy for level of social contact within the population.
- **Social Distancing Mandates:** Imposition & removal of various government mandates.
- **Testing:** Tests conducted per capita (3-day average)
- **Pneumonia seasonality:** relative risk of death by pneumonia (weekly) as COVID-19 has a similar seasonal transmission pattern as pneumonia
- **Mask use:** self-reported mask use, as "always wear a mask" outside the home
- **Pollution:** population-level $PM^{2.5}$ exposure
- **Altitude:** % of pop living under 100m, as incidence & severity of LRI increase at higher elevation.
- **Smoking:** Population smoking prevalence
- **Population density:** % of population living in areas denser than 1,000 people/km^2
- **Lower Respiratory Infections (LRI):** Country-specific mortality rate of LRI as proxy for health system capacity & epidemiological profile