COVID-19 Pandemic Planning Scenarios

CDC and the Office of the Assistant Secretary for Preparedness and Response (ASPR) have developed five COVID-19 Pandemic Planning Scenarios that are designed to help inform decisions by modelers and public health officials who utilize mathematical modeling. The planning scenarios are being used by mathematical modelers throughout the Federal government. Models developed using the data provided in the planning scenarios can help evaluate the potential effects of different community mitigation strategies (e.g., social distancing). The planning scenarios may also be useful to hospital administrators in assessing resource needs and can be used in conjunction with the COVID-19Surge Tool.

Each scenario is based on a set of numerical values for biological and epidemiological characteristics of COVID-19. These values—called *parameter values*—can be used to estimate the possible effects of COVID-19 in U.S. states and localities. The parameter values in each scenario will be updated and augmented over time, as we learn more about the epidemiology of COVID-19.

New data on COVID-19 is available daily; information about its biological and epidemiological characteristics remain limited, and uncertainty remains around nearly all parameter values.

The parameters in the scenarios:

- Are estimates intended to support public health preparedness and planning**.**
- Are **not** predictions of the expected effects of COVID-19.
- Do not reflect the impact of any behavioral changes, social distancing, or other interventions.

The Five Scenarios

The five COVID-19 Pandemic Planning Scenarios (Box 1) represent a range of possible parameters for COVID-19 in the United States. All parameter values are based on current COVID-19 surveillance data and scientific knowledge.

- Scenarios 1 through 4 are based on parameter values that represent the lower and upper bounds of disease severity and viral transmissibility (moderate to very high). The parameter values used in these scenarios are likely to change as we obtain additional data about the upper and lower bounds of disease severity and the transmissibility of SARS-CoV-2, the virus that causes COVID-19.
- Scenario 5 represents a current best estimate about viral transmission and disease severity in the United States, with the same caveat: that the parameter values will change as more data become available.

Parameter values that vary among the Pandemic Planning Scenarios are listed in Table 1, while parameter values common to all five scenarios are listed in Table 2. Definitions of the parameters are provided below, and the source of each parameter value is indicated in the Tables.

The Parameter Values: Definitions

Parameter values that vary across the five COVID-19 Pandemic Planning Scenarios (Table 1) include measures of viral transmissibility, disease severity, and pre-symptomatic and asymptomatic disease transmission. Where sufficient data are available, age-stratified estimates are provided.

Viral Transmissibility

- **Basic reproduction number (R_0):** The average number of people that one person with COVID-19 is likely to infect in a population without any immunity (from previous infection) or any interventions. R_0 is an estimate of how transmissible a pathogen is in a population.

Disease Severity

- **Symptomatic Case Fatality Ratio:** The number of symptomatic individuals who **die** of the disease among all individuals experiencing symptoms from the infection. This parameter is not necessarily equivalent to the number of reported deaths per reported cases, because many cases and deaths are never confirmed to be COVID-19, and there is a lag in time between when people are infected and when they die. This parameter reflects the existing standard of care and may be affected by the introduction of new therapeutics.
- **Symptomatic Case Hospitalization Ratio:** The number of symptomatic individuals who **are hospitalized** from the disease among all individuals experiencing symptoms from the infection. This parameter is not necessarily equivalent to the number of reported hospitalizations per reported cases, because many cases and deaths are never confirmed to be COVID-19, and there is a lag in time between when people are infected and when they die. This parameter reflects the existing standard of care and may be affected by the introduction of new therapeutics.

Pre-symptomatic and Asymptomatic Contribution to Disease Transmission

A **pre-symptomatic case** of COVID-19 is an individual infected with SARS-CoV-2 who has not exhibited symptoms at the time of testing, but who later exhibits symptoms during the course of the infection. An **asymptomatic case** is an individual infected with SARS-CoV-2 who does not exhibit symptoms during the course of infection. Parameter values that measure the pre-symptomatic and asymptomatic contribution to disease transmission include:

- **Percentage of infections that are asymptomatic:** The percentage of persons who are infected with SARS-CoV-2 but never show symptoms of disease. Asymptomatic cases are challenging to identify because individuals do not know they are infected unless they are tested, typically as a part of a scientific study.
- **Infectiousness of asymptomatic individuals relative to symptomatic individuals:** The contribution to transmission of SARS-CoV-2 from asymptomatic individuals compared to the contribution to transmission of SARS-CoV-2 from symptomatic individuals. A parameter value of 50% means that an asymptomatic individual is half as infectious as a symptomatic individual, while a parameter value of 100% means that an asymptomatic individual is just as likely to transmit infection as a symptomatic individual. This parameter is especially challenging to estimate because studies that repeatedly test asymptomatic individuals over time are limited.

Parameter values that do not vary across the five Pandemic Planning Scenarios (Table 2) include:

- **Level of pre-existing immunity to COVID-19 in the community:** The percentage of the U.S. population that had existing immunity to COVID-19 prior to the start of the pandemic beginning in 2019.
- **Percentage of transmission occurring prior to symptom onset:** The percentage of new cases of COVID-19 due to transmission from a person with COVID-19 who transmits infection to others before exhibiting symptoms.
- **Time from exposure to symptom onset:** The number of days between the time when a person has contact with an infected person that results in COVID-19 infection and the first appearance of symptoms.

- **Time between symptom onset in an individual and symptom onset of a second person infected by that individual:** The number of days between the time when a person becomes symptomatic and when the person who they infect becomes symptomatic.

Additional parameter values common to the five COVID-19 Pandemic Planning Scenarios include these seven measures of healthcare usage:

- **Mean number of days from symptom onset to seeking outpatient care**
- **Mean number of days from symptom onset to hospitalization**
- **Mean number of days of hospitalization**
- **Percentage of patients admitted to the ICU among those hospitalized**
- **Percentage of patients on mechanical ventilation among admitted to the ICU**
- **Mean number of days on mechanical ventilation**
- **Median number of days from symptom onset to death**

These healthcare-related parameters (Table 2) are included to assist assessment of resource needs as the pandemic progresses.

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Box 1 Description of the Five COVID-19 Pandemic Planning Scenarios

For each Pandemic Planning Scenario:

- Parameters values for **viral transmissibility** include the Basic Reproduction Number (R_0)
- Parameters values for **disease severity** include Symptomatic Case Fatality Ratio and Symptomatic Case Hospitalization Ratio
- Parameter values for the **pre-symptomatic and asymptomatic contribution** to disease transmission include:
  - Percentage of transmission occurring prior to symptom onset (from pre-symptomatic individuals)
  - Percentage of infections that are asymptomatic
  - Infectiousness of asymptomatic individuals relative to symptomatic individuals

For Pandemic Scenarios 1-4:

- These Scenarios are based on parameter values that represent the lower and upper bounds of disease severity and viral transmissibility (moderate to very high). The parameter values used in these Scenarios are likely to change as we obtain additional data about the upper and lower bounds of disease severity and viral transmissibility of COVID-19.

For Pandemic Scenario 5:

- This Scenario represents a current best estimate about viral transmission and disease severity in the United States, with the same caveat: that the parameter values will change as more data become available.

Scenario 1:

- Lower-bound values for virus transmissibility and disease severity
- Lower percentage of transmission prior to onset of symptoms
- Lower percentage of infections that never have symptoms and lower contribution of those cases to transmission

Scenario 2:
- Lower-bound values for virus transmissibility and disease severity
- Higher percentage of transmission prior to onset of symptoms
- Higher percentage of infections that never have symptoms and higher contribution of those cases to transmission

Scenario 3:
- Upper-bound values for virus transmissibility and disease severity
- Lower percentage of transmission prior to onset of symptoms
- Lower percentage of infections that never have symptoms and lower contribution of those cases to transmission

Scenario 4:
- Upper-bound values for virus transmissibility and disease severity
- Higher percentage of transmission prior to onset of symptoms
- Higher percentage of infections that never have symptoms and higher contribution of those cases to transmission

Scenario 5:
- Parameter values for disease severity, viral transmissibility, and pre-symptomatic and asymptomatic disease transmission that represent the best estimate, based on the latest surveillance data and scientific knowledge. Parameter values are based on data received by CDC prior to 4/29/2020.

Table 1. Parameter Values that vary among the five COVID-19 Pandemic Planning Scenarios. The scenarios are intended to advance public health preparedness and planning**.** They are <u>not</u> predictions or estimates of the expected impact of COVID-19. The parameter values in each scenario will be updated and augmented over time, as we learn more about the epidemiology of COVID-19. Additional parameter values might be added in the future (e.g., population density, household transmission, and/or race and ethnicity).

Parameter values are based on data received by CDC prior to 4/29/2020

Parameter	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5: Current Best Estimate**
R_0 Source: Preliminary COVID-19 estimates, ASPR and CDC	2	2	3	3	2.5
Symptomatic Case Fatality Ratio, stratified by age Source: Preliminary COVID-19 estimates, CDC	0-49 years: 0.0002 50-64 years: 0.001 65+ years: 0.006 Overall: 0.002	0-49 years: 0.0002 50-64 years: 0.001 65+ years: 0.006 Overall: 0.002	0-49 years: 0.001 50-64 years: 0.006 65+ years: 0.032 Overall: 0.010	0-49 years: 0.001 50-64 years: 0.006 65+ years: 0.032 Overall: 0.010	0-49 years: 0.0005 50-64 years: 0.002 65+ years: 0.013 Overall: 0.004

Symptomatic Case Hospitalization Ratio, stratified by age Source: Preliminary COVID-19 estimates, CDC	0–49 years: 0.013 50–64 years: 0.036 65+ years: 0.052 Overall: 0.028	0–49 years: 0.013 50–64 years: 0.036 65+ years: 0.052 Overall: 0.028	0–49 years: 0.026 50–64 years: 0.057 65+ years: 0.10 Overall: 0.041	0–49 years: 0.026 50–64 years: 0.057 65+ years: 0.10 Overall: 0.041	0–49 years: 0.017 50–64 years: 0.045 65+ years: 0.074 Overall: 0.034
Percent of infections that are asymptomatic Source: Preliminary COVID-19 estimates, ASPR and CDC	20%	50%	20%	50%	35%
Infectiousness of asymptomatic individuals relative to symptomatic individuals Source: Assumption, ASPR and CDC	50%	100%	50%	100%	100%

Table 2. Parameter Values Common to the Five COVID-19 Pandemic Planning Scenarios. The parameter values are likely to change as we obtain additional data about disease severity and viral transmissibility of COVID-19.

Parameter values are based on data received by CDC prior to 4/29/2020

Pre-existing immunity Source: Assumption, ASPR and CDC	No pre-existing immunity before the pandemic began in 2019. It is assumed that all members of the U.S. population were susceptible to infection prior to the pandemic.
Percentage of transmission occurring prior to symptom onset: Source: Preliminary COVID-19 estimates, ASPR and CDC	40%
Time from exposure to symptom onset Source: Pre-publication COVID-19 estimates*	~6 days (mean)
Time between symptom onset in an individual and symptom onset of a second person infected by that individual Source: Pre-publication COVID-19 estimates	~6 days (mean)
Parameter Values Related to Healthcare Usage	

Time to seek care (outpatient) Source: Survey of persons with Influenza like illness (ILI), CDC[†]	≤2 days: 35% 3–7 days: 50% ≥8 days: 25%
Mean number of days from symptom onset to hospitalization (standard deviation) Source: Preliminary COVID-19 estimates, CDC[§]	0-49 years: 6.9 (5.0) days 50-64 years: 7.2 (5.3) days ≥65 years: 6.2 (5.7) days
Mean number of days of hospitalization among those not admitted to ICU (standard deviation) [¶] Source: Preliminary COVID-19 estimates**,** CDC	0-49 years: 3.9 (3.7) days 50-64 years: 4.9 (4.3) days ≥65 years: 6.3 (5.1) days
Mean number of days of hospitalization among those admitted to ICU (standard deviation) [¶] Source: Preliminary COVID-19 estimates**,** CDC	0-49 years: 9.5 (7.2) days 50-64 years: 10.5 (7.0) days ≥65 years: 10.0 (6.8) days
Percent admitted to ICU among those hospitalized Source: Preliminary COVID-19 estimates, CDC	0-49 years: 21.9% 50-64 years: 29.2% ≥65 years: 26.8%
Percent on mechanical ventilation among those in ICU Source: Preliminary COVID-19 estimates, CDC	0-49 years: 72.1% 50-64 years: 77.6% ≥65 years: 75.5%
Mean number of days of mechanical ventilation (standard deviation) Source: Preliminary COVID-19 estimates, CDC	Overall: 5.5 (5.3) days
Mean number of days from symptom onset to death (standard deviation) Source: Preliminary COVID-19 estimates, CDC[§]	0-49 years: 14.9 (7.7) days 50-64 years: 15.3 (8.1) days ≥65 years: 12.9 (7.6) days
Mean number of days from death to reporting (standard deviation) Source: Preliminary COVID-19 estimates, CDC[**]	0-49 years: 7.1 (7.7) days 50-64 years: 7.2 (7.7) days ≥65 years: 6.6 (7.3) days

*Khalili, M., Karamouzian, M., Nasiri, N., Javadi, S., Mirzazadeh, A., & Sharifi, H. (2020). Epidemiological Characteristics of COVID-19: A Systemic Review and Meta-Analysis. *medRxiv*.

† Biggerstaff, M., Jhung, M. A., Reed, C., Fry, A. M., Balluz, L., & Finelli, L. (2014). Influenza-like illness, the time to seek healthcare, and influenza antiviral receipt during the 2010–2011 influenza season—United States. *The Journal of infectious diseases*, *210*(4), 535-544.

§ Estimates only include onset dates between March 1, 2020 – March 31, 2020 to ensure cases have had sufficient time to observe the outcome (hospital admission or death).

¶ Estimates only include hospital admission dates between March 1, 2020 – March 31, 2020 to ensure cases have had sufficient time to observe the outcome (hospital discharge or death).

** Estimates only include death dates between March 1, 2020 – March 31, 2020 to ensure sufficient time for reporting