SARS-CoV-2 (COVID-19) Modeling (Version 2.0)
April 10th, 2020

Stefan Gildemeister, State Health Economist
Eva Enns, Associate Professor, School of Public Health | Shalini Kulasingam, Associate Professor, School of Public Health

PROTECTING, MAINTAINING AND IMPROVING THE HEALTH OF ALL MINNESOTANS
Overview

- Data that helps inform Minnesota’s epidemic response
- Updates to the Minnesota COVID-19 model
- Findings
- Detail from four scenarios
- Limitations and next steps
Data that Informs Epidemic Response

- Traditional public health data
  - Syndromic surveillance – health care/surveys/more
  - ILI/flu like symptoms
  - Death records
  - Persons tested

- Data on health care capacity (PPE, ICU/vents, health care workers)

- Information from other states

- Evidence from the literature/CDC

- Output from mathematical disease modeling
Cases per 100k People After First 100 Confirmed Cases, MN and Select States
(Based on MDH Report Date, Cumulative)

Source: MDH Health Economics Program analysis of several state’s department of public health, covidtracking.com, and publicly accessed news source COVID-19 reporting. Information is as a point in time and can vary by source. State resident population is based on Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2019 (NST-EST2019-01); U.S. Census Bureau, Population Division; December 2019.

Day 0 is based on first date state reported having 100 COVID-19 cases, resulting in different time durations by state. Cases may include non-residents of the state.
Percent of Positive COVID-19 Tests and Tests per 100k People, All States (Cumulative)

Source: MDH Health Economics Program analysis of several state’s department of public health, covidtracking.com, and publicly accessed news source COVID-19 reporting. Information is as of 4/3/2020 and can vary by source. Cases and numbers of tests may include non-residents of the state. State resident population is based on Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2019 (NST-EST2019-01); U.S. Census Bureau, Population Division; December 2019.

Based on data from all states as of 4/3/20. Some differences between states are due to where they are in the disease curve, the age and health distribution of the state, and mitigation steps taken by the states. This graph cannot determine which of these factors is impacting where states are on this scatterplot. Percent of positive tests is calculated as cases divided by number of tests. The number of tests is assumed to include private and public lab testing; however, not all private labs submit testing data.
Minnesota’s COVID-19 Model
A Partnership with the School of Public Health
Susceptible, Exposed, Infected, Recovered (SEIR)

▪ Model structure has been used to forecast outcomes for other coronaviruses - SARS and MERS

▪ Same structure used by the most sophisticated COVID-19 models, because it:
  ▪ Accounts for mechanism of COVID 19 disease spread, or its natural history
  ▪ Accommodates biologic evidence of incubation period prior to infectious period

▪ Not based solely on curve-fitting to observed deaths (IHME)
• Latent period: 5 days
• Infectious period: 8 days
• $R_0$: $\sim 3.87$ (2.5-4.7)
• Days in hospital: 13.3 (7-23 days)
• Days in ICU: 10.3 days (4-17 days)
• If no ICU bed available, mortality risk 1.5x – 16.5x higher (depends on age)
• Increased mortality factor with ≥1 comorbidity: 7.6x
• Available ICU beds: 2,200
Refinements in Model, v.2 Drive Changes in Estimates

- Fitted model to **actual MN COVID-19 deaths** (starting w/March 23, 2020) → further along in the epidemic?
- Updated **parameter estimates using newly available data, incl. US**
  - Lower proportion of cases requiring hospitalization (asymptomatic patient role) → lower expected hospitalizations
  - Higher R0 than previously thought → faster spread & quicker time to peak
  - Lower length of hospital stay
- Updated **age & comorbidity distribution** of MN population
- Incorporated uncertainty estimates
Primary Findings

- Model & data changes since model v.1 resulted in:
  - Modestly shortened time to peak infection/capacity
  - Fewer estimated deaths

- Most effective factors to reduce mortality:
  - Increased ICU capacity (surge capacity coming online)
  - Asking vulnerable to stay home

- Extending Stay-at-Home order would extend time to peak

- Forms of longer-term reduction in contacts can further reduce deaths & ICU demand
## Modeled Scenarios

<table>
<thead>
<tr>
<th>Type and Duration of Mitigation</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 3.1</th>
<th>Scenario 3.2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No mitigation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SHO + physical distancing (ends May 1)</strong></td>
<td></td>
<td>3/17 to 3/26 (10 days)</td>
<td>3/17 to 3/26 (10 days)</td>
<td>3/17 to 3/26 (10 days)</td>
<td>3/17 to 3/26 (10 days)</td>
<td>3/17 to 3/26 (10 days)</td>
</tr>
<tr>
<td><strong>Long-term SHO for most vulnerable</strong></td>
<td>3/27 to 4/10 (14 days)</td>
<td>3/27 to 4/10 (14 days)</td>
<td>3/27 to 4/10 (14 days)</td>
<td>3/27 to 5/8 (6 weeks/42 days)</td>
<td>3/27 to 5/8 (6 weeks/42 days)</td>
<td>3/27 to 4/10 (14 days)</td>
</tr>
<tr>
<td><strong>Extending SHO for all (by 4 weeks)</strong></td>
<td></td>
<td>4/10 to 5/1 (21 days)</td>
<td>4/10 to 5/1 (21 days)</td>
<td>5/9 to 5/30 (21 days)</td>
<td>4/10 to 6/12 (9 weeks/63 days)</td>
<td>4/10 to 5/1 (21 days)</td>
</tr>
<tr>
<td><strong>Extending physical distancing (by 6 weeks)</strong></td>
<td>3/17 to 3/26 (10 days)</td>
<td>4/10 to 5/1 (21 days)</td>
<td>4/10 to 5/1 (21 days)</td>
<td>5/9 to 5/30 (21 days)</td>
<td>4/10 to 6/12 (9 weeks/63 days)</td>
<td>5/2 to 7/31 (13 weeks/90 days or 30 days after peak deaths)</td>
</tr>
<tr>
<td><strong>Permanent modest reduction in contacts until end of epidemic or treatment</strong></td>
<td>3/17 to 3/26 (10 days)</td>
<td>4/10 to 5/1 (21 days)</td>
<td>4/10 to 5/1 (21 days)</td>
<td>5/9 to 5/30 (21 days)</td>
<td>4/10 to 6/12 (9 weeks/63 days)</td>
<td>5/2 to 7/31 (13 weeks/90 days or 30 days after peak deaths)</td>
</tr>
</tbody>
</table>

**one cell = approximately 5 days**

- **High form of social distancing requiring businesses to accommodate employees/customers, reduction of contacts by 20pct**
- **Physical distancing, reduction in contacts by 50pct**
- **Requirement for vulnerable people to remain at home, reduction of contacts by 50pct**
- **Stay-at-home order, reduction of contacts by 80pct**

---

### Scenario 1 (No mitigation)

- **Type and Duration of Mitigation:**
  - 3/17 to 3/26 (10 days)
  - 3/27 to 4/10 (14 days)
  - 4/10 to 5/1 (21 days)

### Scenario 2 (SHO + physical distancing (ends May 1))

- **Type and Duration of Mitigation:**
  - 3/17 to 3/26 (10 days)
  - 3/27 to 4/10 (14 days)
  - 4/10 to 5/1 (21 days)

### Scenario 3 (Long-term SHO for most vulnerable)

- **Type and Duration of Mitigation:**
  - 3/17 to 3/26 (10 days)
  - 3/27 to 4/10 (14 days)
  - 4/10 to 5/1 (21 days)

### Scenario 4 (Extending SHO for all (by 4 weeks))

- **Type and Duration of Mitigation:**
  - 3/17 to 3/26 (10 days)
  - 3/27 to 4/10 (14 days)
  - 4/10 to 5/1 (21 days)

### Scenario 3.1 (Extending physical distancing (by 6 weeks))

- **Type and Duration of Mitigation:**
  - 3/17 to 3/26 (10 days)
  - 3/27 to 4/10 (14 days)
  - 4/10 to 5/1 (21 days)

### Scenario 3.2 (Long-term slowed contacts for all)

- **Type and Duration of Mitigation:**
  - 3/17 to 3/26 (10 days)
  - 3/27 to 4/10 (14 days)
  - 4/10 to 5/1 (21 days)
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Days till Peak</th>
<th>Days till ICU</th>
<th>Top ICU Demand</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where We Started</td>
<td>7 weeks (May 11)</td>
<td>4 weeks (April 20)</td>
<td>3,300</td>
<td>50,000</td>
</tr>
<tr>
<td>Scenario 1 (235 ICU)/#</td>
<td>7 weeks (May 11)</td>
<td>4 weeks (April 20)</td>
<td>3,300</td>
<td>50,000</td>
</tr>
<tr>
<td>Scenario 2 (2,200 ICU)*</td>
<td>11 weeks (June 8)</td>
<td>11 week (June 8)</td>
<td>4,500</td>
<td>41,000</td>
</tr>
<tr>
<td>Long term SHO for most vulnerable</td>
<td>Scenario 3</td>
<td>11 weeks (June 8)</td>
<td>11 weeks (June 8)</td>
<td>3,700</td>
</tr>
<tr>
<td>Extending SHO for all (by 4 weeks)</td>
<td>Scenario 4</td>
<td>16 weeks (July 13)</td>
<td>16 weeks (July 13)</td>
<td>3,700</td>
</tr>
<tr>
<td>Extending physical distancing (by 6 weeks)</td>
<td>Scenario 3.1</td>
<td>15 weeks (July 6)</td>
<td>14 week (June 29)</td>
<td>3,300</td>
</tr>
<tr>
<td>Long-term slowed contacts for all</td>
<td>Scenario 3.2</td>
<td>12 weeks (June 15)</td>
<td>12 weeks (June 15)</td>
<td>3,400</td>
</tr>
</tbody>
</table>

#Volume of available ICU beds in early March
*Estimated volume of ICU beds (including vents) available for COVID-19 patients only.
# All Outcome Estimates by Scenario [with Estimates of Uncertainty]

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Days till Peak</th>
<th>Days till ICU</th>
<th>Top ICU Demand</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Where We Started</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1 (235 ICU)#</td>
<td>7 weeks (May 11)</td>
<td>4 weeks (April 20)</td>
<td>3,300 [2,000 to 4,800]</td>
<td>50,000 [34,000 to 68,000]</td>
</tr>
<tr>
<td></td>
<td>[5 to 10 weeks]</td>
<td>[2 to 5 weeks]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 2 (2,200 ICU)*</td>
<td>11 weeks (June 8)</td>
<td>11 week (June 8)</td>
<td>4,500 [3,200 to 6,000]</td>
<td>41,000 [22,000 to 59,000]</td>
</tr>
<tr>
<td></td>
<td>[9 to 15 weeks]</td>
<td>[8 to 14 weeks]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Long term SHO for most vulnerable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 3</td>
<td>11 weeks (June 8)</td>
<td>11 weeks (June 8)</td>
<td>3,700 [2,700 to 4,900]</td>
<td>22,000 [9,000 to 36,000]</td>
</tr>
<tr>
<td></td>
<td>[9 to 15 weeks]</td>
<td>[9 to 15 weeks]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Extending SHO for all (by 4 weeks)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 4</td>
<td>16 weeks (July 13)</td>
<td>16 weeks (July 13)</td>
<td>3,700 [2,700 to 4,800]</td>
<td>22,000 [9,000 to 36,000]</td>
</tr>
<tr>
<td></td>
<td>[13 to 21 weeks]</td>
<td>[12 to 21 weeks]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Extending physical distancing (by 6 weeks)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 3.1</td>
<td>15 weeks (July 6)</td>
<td>14 week (June 29)</td>
<td>3,300 [2,600 to 4,000]</td>
<td>20,000 [9,000 to 33,000]</td>
</tr>
<tr>
<td></td>
<td>[10 to 20 weeks]</td>
<td>[9 to 19 weeks]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Long-term slowed contacts for all</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 3.2</td>
<td>12 weeks (June 15)</td>
<td>12 weeks (June 15)</td>
<td>3,400 [2,400 to 4,600]</td>
<td>22,000 [6,000 to 35,000]</td>
</tr>
<tr>
<td></td>
<td>[9 to 18 months]</td>
<td>[9 to 17 weeks]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Volume of available ICU beds in early March
*Estimated volume of ICU beds (including vents) available for COVID-19 patients only.
Continued distancing among vulnerable reduces peak demand (strategy 2 vs. 3)

Extending SHO delays peak demand (strategy 3 vs. 4)
ICU Demand, Scenarios 2 vs 3, 3.1, 3.2 (extended social distancing)

Extended social distancing following SHO conclusion reduces and delays demand (strategy 3 vs. 3.1)
Sustained, general behavior change modestly reduces peak demand (strategy 3 vs. 3.2)
Next Steps: Model Refinement/Enhancement

- Continue to update model based on Minnesota data
  - Fit to observed deaths
  - New data on contact pattern changes (in the field now)
- Model on/off scenarios of mitigation
- Incorporate asymptomatic infection (data dependent)
- Evaluate robustness of peak ICU demand and incorporate deaths via hospitalization and infections (data dependent)
- Examine geographic variability in the epidemic using local/county data
Next Steps: Documentation & Release

- Documentation released April 10
  - Technical documentation
  - FAQ on key questions
  - Infographic
- Additional model refinement and enhancement: within next two weeks
- Release of model interface and code: aiming for late April

Additional documentation available at: https://mn.gov/covid19/
Deaths in MN may be due to clustering in congregate setting -- the shape of the curve could change considerably over the next few weeks.

Deaths from hospitalizations or infections that weren’t diagnosed aren’t accounted for currently.

Role of asymptomatic infection in transmission is unclear.

Much is still unknown about the pathogen & data on key parameters are often from international settings or are missing.

Analysis does not account for economic costs or other side effects of mitigation (e.g., psychological effects, income, state’s economy).
Team Acknowledgement

UMN
- Marina Kirkeide
- Abhinav Mehta
- Gregory Knowlton
- Richard MacLehose
- Kumi Smith
- Kelly Searle
- Ran Zhao

MDH
- Pam Mink
- Alisha Simon
- Erinn Sanstead
- Plus a large team of epidemiologists
Thank You!

University of Minnesota School of Public Health
Eva Enns (eenns@umn.edu) | Shalini Kulasingam (kulas016@umn.edu)
Media: unews@umn.edu

Minnesota Department of Health
Stefan Gildemeister (Stefan.Gildemeister@state.mn.us)
Media: health.media@state.mn.us

More on COVID-19 in MN
Coronavirus Disease in Minnesota (mn.gov/covid19/) | MDH COVID-19 (www.health.state.mn.us/diseases/coronavirus/)
Scenario 1: No Mitigation

- Hypothetical scenario of no reduction in person-to-person contact

- Outcomes (uncertainty at 95% CI):
  - Week of peak infections: 7 (5 to 10) weeks
  - Week ICU bed capacity reached (235 beds): 4 (2 to 5) weeks
  - Max ICU demand: 3,200 (2,200 to 4,800) ICU/vents
  - Overall deaths: 50,000 (34,000 to 68,000) individuals
Scenario 2: Stay at Home Order (Ends May 1)

- Change in person-to-person contacts:
  - Significant mitigation (2 weeks), reduction by 80%
  - Followed by physical distancing (3 weeks), reduction by 50% percent

- Outcomes (uncertainty at 95% CI):
  - Week of peak infections: 11 (9 to 15) weeks
  - Week ICU bed capacity reached (2,200 beds): 15 (8 to 14) weeks
  - Max ICU demand: 4,500 (3,200 to 6,000) ICU w/vents
  - Overall deaths: 41,000 (22,000 to 59,000) individuals
Scenario 3: Stay at Home Order Followed by Extended Stay at Home for Vulnerable

- **Change in person-to-person contacts:**
  - Significant mitigation (2 weeks), reduction by 80%
  - Followed by physical distancing (3 weeks), reduction by 50%
  - Extended reduced contact for vulnerable, 30 days past the peak of deaths, reduction 50%

- **Outcomes (uncertainty at 95% CI):**
  - Week of peak infections: 11 (9 to 15) weeks
  - Week ICU bed capacity reached (2,200 beds): 11 (9 to 15) weeks
  - Max ICU demand: 3,700 (2,700 to 4,900) ICU/vents
  - Overall deaths: 22,000 (9,000 - 36,000) individuals
Scenario 4: Extended Stay at Home Order (Total 9 Weeks)

- Change in person-to-person contacts:
  - Stay at Home order (6 weeks), reduction by 80%
  - Followed by physical distancing (3 weeks), reduction by 50%
  - Extended reduced contact for vulnerable, 30 days past the peak of deaths, reduction 50%

- Outcomes (uncertainty at 95% CI):
  - Week of peak infections: 14 (11 to 19) weeks
  - Week ICU bed capacity reached (2,200 beds): 16 (13 to 21) weeks
  - Max ICU demand: 3,700 (2,600 to 4,800) ICU/vents
  - Overall deaths: 22,000 (9,000 - 35,000) individuals
Scenario 3.1: Stay at Home Order with Extended Distancing

- Change in person-to-person contacts:
  - Stay at Home order (9 weeks), reduction by 80%
  - Followed by extended distancing (9 weeks), reduction by 50%
  - Extended reduced contact for vulnerable, 30 days past the peak of deaths (reduction 50%)

- Outcomes (uncertainty at 95 CI):
  - Week of peak infections: 15 (10 to 20) weeks
  - Week ICU bed capacity reached (2,200 beds): 14 (9 to 19) weeks
  - Max ICU demand: 3,300 (2,600 to 4,000) ICU/vents
  - Overall deaths: 20,000 (9,000 to 33,000) individuals
Scenario 3.2: Stay at Home order with Permanent Lower Levels of Contact

- Change in person-to-person contacts:
  - Stay at Home order, reduction by 80%
  - Followed by physical distancing (3 weeks), reduction by 50%
  - Continued Stay at Home order for vulnerable), extended 30 days past the peak deaths (reduction 50%) and permanent reduction in contacts (20%)

- Outcomes (uncertainty at 95% CI):
  - Week of peak infections: 12 (9 to 18) weeks
  - Week ICU bed capacity reached (2,200 beds): 12 (9 to 17) weeks
  - Max ICU demand: 3,400 (2,400 to 4,600) ICU/vents
  - Overall deaths: 20,000 (6,000 to 35,000) individuals