Vanderbilt Health Policy COVID-19 Modeling for Tennessee

SARS-CoV-2 was first reported in Tennessee on March 5, 2020. Because this is a new virus, there is no vaccine and no known treatment, and the entire population is susceptible. Containing it, and reducing loss of life in Tennessee, requires understanding the current trajectory, anticipating possible increases or decreases in infections, and implementing smart strategies to keep the virus from spreading.

As hospitals prepared for an influx of patients with the potential to outstrip available beds and clinical workforce, Tennessee cities and counties began on March 18, 2020 to implement public health strategies, such as recommending that citizens stay home and closing certain non-essential businesses. Public health officials established testing and began to put in place tracking of cases and hospitalizations along with recommendations that people who were exposed or test positive separate themselves from others so as not to share the virus. On March 23, the Governor issued an executive order urging a statewide “Safer at Home” strategy. This was enhanced with an additional executive order released on April 2. The goal of all of these approaches is to slow the spread of the disease so as not to overwhelm the health system, and to give health care researchers time to develop a vaccine and treatment options.

This data brief describes the current state of the epidemic in Tennessee and presents a range of scenarios for how the epidemic might evolve. We also make recommendations about how to keep the spread of the virus within the capabilities of Tennessee hospitals to manage patients needing hospital care. A critical takeaway of our assessments of state data to date, and our modeling assessments of a range of scenarios moving forward, is the importance of continued social distancing until we reach a sustained drop in cases. Any reduction in social distancing must be paired with reliable and speedy testing and contact tracing to keep disease spread under control.

How these models were developed

The work presented here represents both description and prediction. The descriptive data used include publicly available data about cases reported across Tennessee as well as additional data from the Tennessee Department of Health about testing.

The projection model used is based on a SEIR epidemiologic model, which stands for susceptible, exposed, infected and recovered. This type of model allows us to use data and emerging research to project how widely and quickly the virus is spreading through a population as individuals are exposed to the virus, become infected, infect others, and then do or do not recover. As individuals recover, they are removed from the susceptible group under the assumption that they gain some level of immunity.

We have enhanced our SEIR model to accommodate the unique features of SARS-CoV-2 and the current testing environment. These enhancements include the recognition that not all cases are tested, that there are often delays in testing, and that some cases are asymptomatic or mild enough that individuals may not require or seek testing and/or treatment.

Unlike other leading models, the Vanderbilt model is “tuned” to data from Tennessee. This means that predictions from the model for the current day closely match what has been seen in our state to date; our model is designed on the principle that if a model cannot predict what is known today, then it cannot be relied upon to predict what is unknown in the future. Specifically, our model draws on daily updates to positive case reports across the state. This allows us to trace out how the trajectory of transmission patterns has changed in different areas of the state over time.

One key parameter we have tuned to Tennessee is the transmission number, which summarizes the average number of additional infections caused by an infected individual. Emerging research from the CDC indicates that the transmission number for SARS-CoV-2 in an uncontrolled epidemic may be as high as 5.7. Our evaluation of Tennessee's initial experience with SARS-CoV-2 prior to social distancing is consistent with this number.

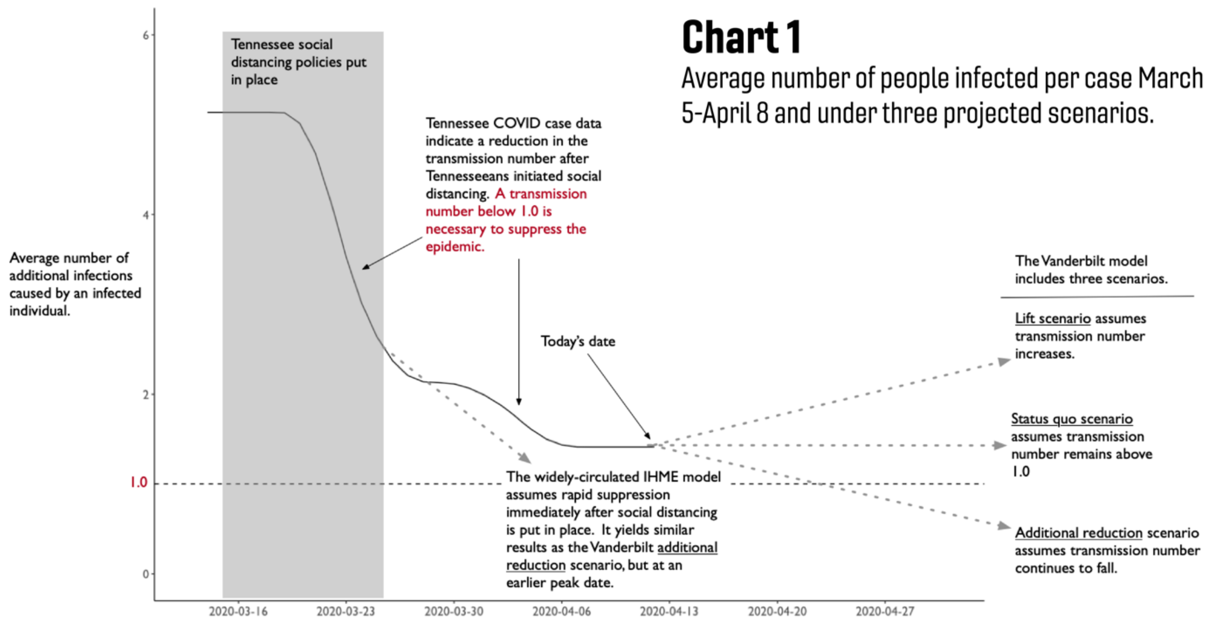
The effective transmission number can change over time due to policies and changes in people's behavior that affect how many other people a given infected person comes into contact with or that reduce the risk of transmission (e.g., through more frequent handwashing and masks). To suppress the epidemic, a transmission number less than 1.0 must be sustained. Many models assume a one-time change in the transmission number as a result of policy and/or behavioral changes. Because our model traces out the effective transmission number over time, we can use this information to both evaluate the relative success of policy changes to date, and to predict hypothetical changes to the transmission number in the future.

We project future scenarios under three sets of assumptions: (1) if the progress to date is maintained (**status quo scenario**); (2) if the state achieves additional progress (**additional reduction scenario**); and (3) if the progress we have achieved gradually "unwinds" as social distancing policy is relaxed and is not met with additional strategies to keep the epidemic under control (**lift scenario**). It is important to emphasize that the lift scenario is intended highlight the high transmissibility of SARS-CoV-2 and how quickly a second wave of infection could arrive if additional mitigation strategies are not put in place to keep disease spread low in the absence of widespread social distancing.

Rate of Spread of COVID-19 in Tennessee

As of April 9, 2020, 4,634 cases of COVID had been reported in Tennessee, including 505 hospitalizations and 94 deaths.

As noted above, our models track the number of people an infected person is likely to infect in turn as a key metric. We want this number to drop below 1 to stop an infection from spreading: if each person infects fewer than one person then the total number of cases will drop. We estimate that, in Tennessee, this number has declined from each case infecting over 5 new people in mid-March to approximately 1.4 new people as of the week of April 6. This is substantial progress that was achieved in very short order as a result of social distancing now being practiced by many Tennesseans. However, we also note while the transmission number continues to decline, the rate at which it has declined indicates that the state will need further progress over the coming weeks to bring the number below 1.



We also note that small changes in this transmission number can increase the number of people any given person will infect, which in turn can have a substantial effect on the number of cases in a community.

Chart 1 traces out this key metric over time for the state of Tennessee as a whole since the first reported infection in the state. It shows the substantial progress achieved by Tennesseans in quickly reducing transmissions in the period just after social distancing policies were put in place. The chart also shows the future path of the rate of new infections per case under each of our three scenarios and notes key differences between the scenarios we model and the widely circulated IHME model.

Variation Across the State

A unique advantage of our model is that we can observe rates of spread of the virus in sub-state regions and we plan to use that information to predict regional needs for hospitals beds. The chart below shows the average number of new infections from each case by health care coalition. The corresponding color-coded map of the state is below. The line for each of these regions starts on the date the first case is reported in the Department of Health data. The downward trajectory of the lines over time show that the rate of transmission is falling over time in every region of the state.

Chart 2 shows that the Highland region, including the metropolitan Nashville region, was the first region to show a decline in the transmission rate. This is consistent with Nashville issuing the first “safer at home” order. Other areas followed a similar trajectory, with the Western (WATCH-7) region lagging the rest of the state. It is notable that all regions of the state have now, however, converged to an average number of new infections per case of approximately 1.4.

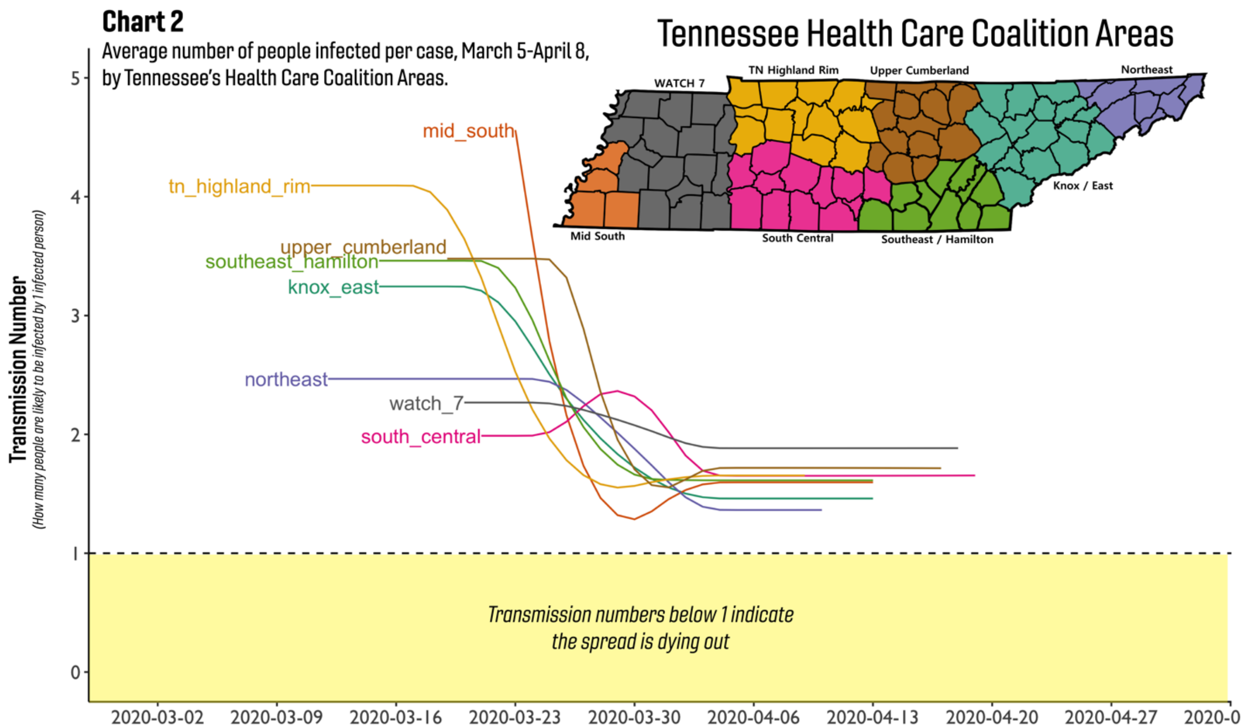


Chart 2 is also notable in that highlights that transmission of the virus varies across urban and rural areas of the state. This is not surprising: the average number of contacts someone has with other individuals in an urban area is likely higher than in rural areas. As such, before social distancing is put into place the average number of new people infected per case is lower in rural regions than in urban regions. The chart also makes clear, however, that progress in reducing transmissions in rural areas of the state lagged progress in urban areas of the state by 1-2 weeks. Moreover, no region of the state has achieved a transmission number below 1.

These transmission patterns are also apparent in our descriptive analyses of total cases and new cases over time. **Chart 3** highlights this progress.

In other countries that have successfully turned the corner on COVID-19, we see a pattern of rapid and substantial increase in cases, followed by a sharp drop, or “ejection,” off of the case growth curve. This is clear from the case trajectory plotted for South Korea in the lower right corner of **Chart 3** below. At the inflection point, the rate of increase in cases plateaus for a period before dropping. This plateau is fragile in that scaling back interventions or processes for stopping disease spread will put a country or state back on the upward trajectory.

Current data suggest that Tennessee may be on that plateau, and with sustained social distancing and other public health interventions, could turn the corner and may soon see a sustained drop in daily case growth numbers. However, echoing our regional analysis of transmissions above, the chart also makes clear that non-metro areas of the state continue to see higher growth in caseloads than metro areas.

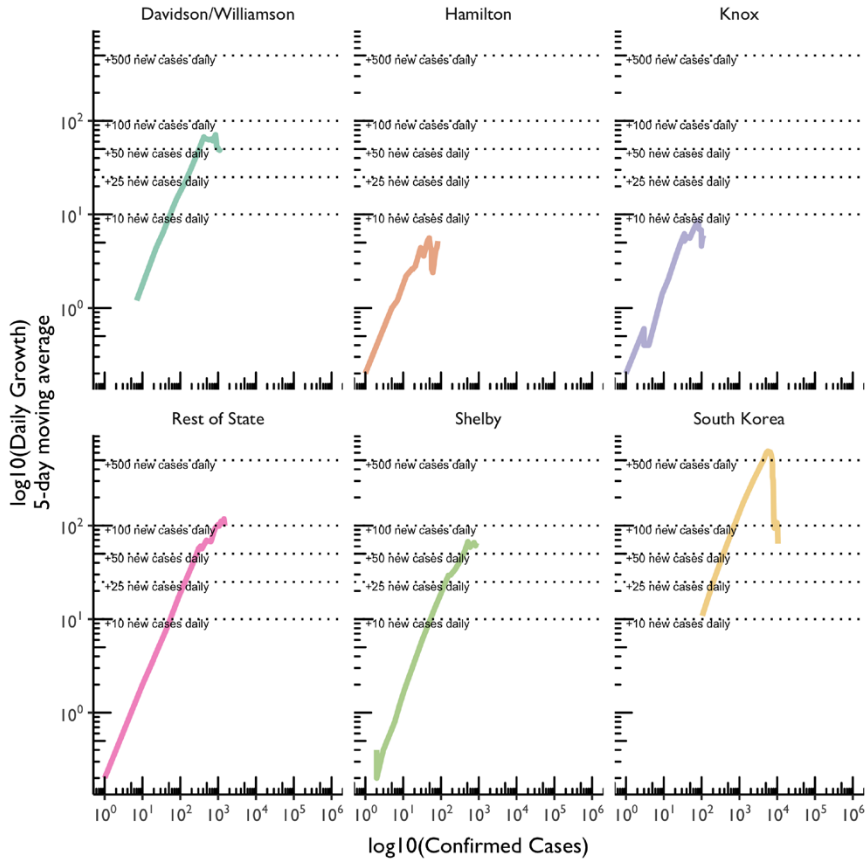


Chart 3

Daily case growth and number of confirmed cases, for key counties and the rest of Tennessee compared to South Korea.

Projecting Hospital Capacity Needs

We next turn to our model to estimate the cumulative numbers of cases and fatalities, as well as the number of hospitalizations likely on a peak day for the three scenarios. As noted above, the first scenario is a lifting of social distancing that begins to "unwind" the progress seen to date and returns Tennessee to the rate of increase experienced before social distancing was implemented. The second scenario assumes that social distancing continues and as a result the status quo transmission number remains around 1.4, and the third scenario depicts what would happen if social distancing measures decrease the rate of spread even more into the future.

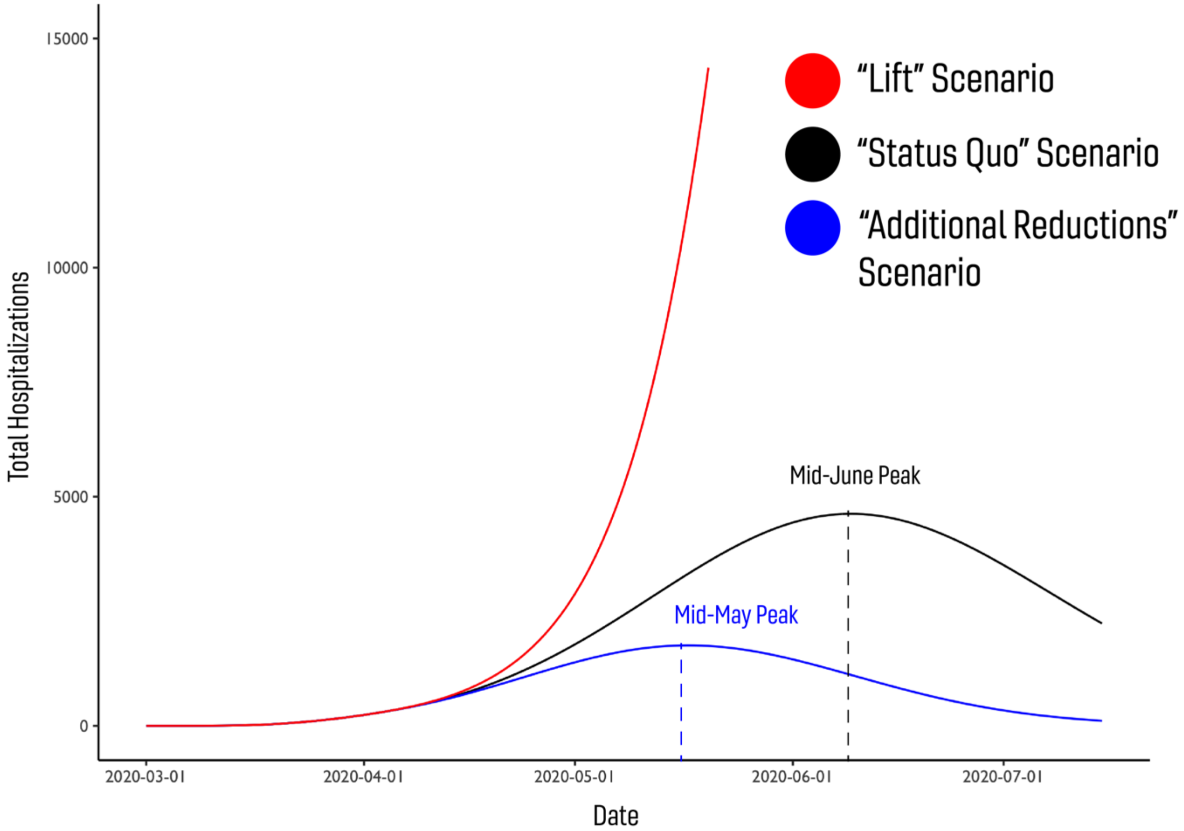
Additional reduction (optimistic) scenario assumes that gains from social distancing continue to grow through April and May; by mid-May we don't see an increase in cases because Tennessee has achieved an R of below 1. Under this scenario hospital capacity could be sufficient to care for all patients needing inpatient level care.

Status quo scenario assumes the state maintains the current rate of disease spread through May and projects a peak in hospitalizations in mid-June that could stress the capacity of the state hospital system.

Lifting social distancing scenario overwhelms hospital capacity if done prematurely and without widespread testing and contact tracing in place. Under this scenario, 13% of the population has tested positive and at the peak close to 50,000 Tennesseans are sick enough to require hospitalization.

Chart 4 traces out the demand for hospital care over time under each of the scenarios. We assume that 4.5% of people who experience COVID-19 symptoms need inpatient hospital care.

Chart 4:
Projected hospitalizations over time.



At this point in time we think there is considerable uncertainty in projecting deaths under our scenarios. First, we believe that, due to limitations in the availability of testing, the number of deaths due to COVID-19 is likely underreported at present. Second, while the average age of the initial set of cases in Tennessee was relatively young, the health of Tennesseans overall is below the national average. Thus, both state patterns and national patterns in death rates may not be good guides to the future. Finally, we note that under scenarios in which the health system is overburdened there may be more deaths than our model would project because an overburdened health care system would leave some people unable to receive needed care. Nonetheless, we would note that the reported number of deaths due to COVID-19 in Tennessee has nearly doubled in less than a week, from 50 on April 4 to 94 on April 9. Given the typical time frame between infection and death, this doubling likely reflects the infections that arose during a time period when the state was reporting fewer than 500 positive tests.

Finally, it critical to emphasize that the real progress seen to date could reverse; premature easement of current policy without sufficient second-line strategies in place will likely cause progress to unravel. The underlying virus is highly infectious and social distancing has reduced the risk of infection but does not confer immunity to people who haven't been infected yet. The moderation in the growth of daily case numbers is positive news, but also underscores the large fraction of the Tennessee population that remains susceptible to infection. As such, we continue to stress persistence in social distancing until a sustained ebb in the epidemic is reached, and at which time social distancing can begin to be replaced with reliable and speedy testing and contact tracing – and other risk mitigation strategies -- to keep disease spread under control and reduce the loss of life due to COVID-19.

What's the Takeaway?

A critical takeaway of our model is the importance of continued social distancing until we reach a sustained drop in cases. Any reduction in social distancing must be paired with reliable and speedy testing and contact tracing to keep disease spread under control.

Our model suggests that the Tennessee epidemic could have been sparked by as few as 10 people. Six weeks later we have 4,634 reported cases who have tested positive. The true number of cases is substantially higher because there are asymptomatic individuals as well as individuals who may be symptomatic who have not yet received a test or a test result.

This highlights the infectiousness of this virus and underscores the significant risk of a second wave of the infection that could be started by just a few infected people. We currently have thousands of infected people who could act as "sparks" for rapid infection growth in Tennessee, leading to a wildfire of cases, hospitalizations, and deaths. Any lifting of current policies must be done carefully, with adequate public health strategies fully operational to ensure the COVID-19 virus does not return to spreading rapidly through our population.

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