POST-PUBLICATION CORRECTION:
The 523 hospitalizations on pages 4 & 5 and exhibit 2 should be 490.
See website for details

COVID-19 in North Carolina

Flipping the Switch or Adjusting the Dimmer? A Data-Driven Approach for Informing North Carolina's Reopening Strategy

Aaron McKethan, PhD;
Hilary Campbell, PharmD, JD;
M. Alan Brookhart, PhD; Alex Breskin, PhD;
Mark Holmes, PhD

- North Carolina's early start in addressing COVID-19 aggressively is paying off. Instituting policies to increase social distancing have likely helped the state avoid a more dire outlook that was possible had the state chosen a different path.
- However, COVID-19 remains a serious threat to North Carolina. There are serious tradeoffs to be considered in any path forward. As we explore ways to reopen the state and the economy, we need to implement any reopening plan gradually so people can go back to work while continuing to impede the spread of the virus.
- Core elements of the reopening plan must include proven outbreak containment activities, such as rapid testing and contact tracing, careful monitoring of hospital capacity, and ensuring the safety and supply of the healthcare workforce.
- To inform the reopening plan, an informal North Carolina COVID-19 research collaborative[1] is currently preparing forecasts with the latest available data to update a prior brief released April 6th. In the meantime, today's brief outlines an incremental "dimmer switch" strategy to inform potential reopening options with an analytical approach to inform the pace of reopening using updated data and near-term projections.

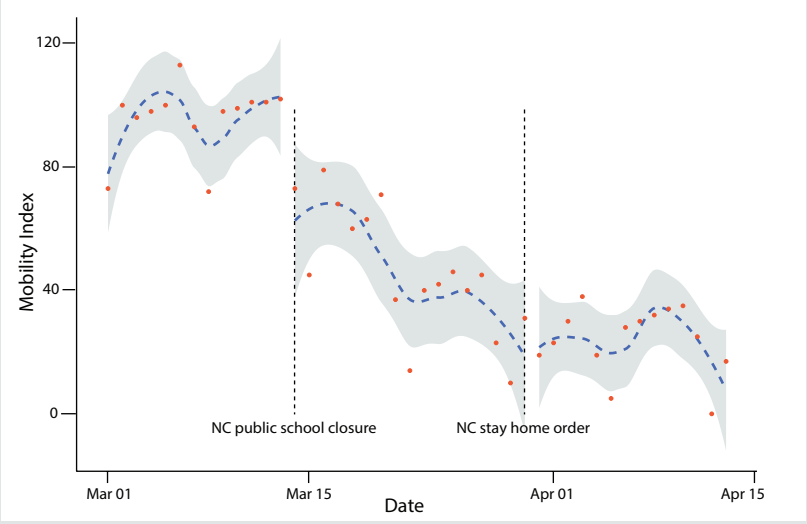
Introduction

Early in an outbreak of a novel infectious viral disease like COVID-19, one strategy to mitigate the spread of the virus is to keep people separated from one another as much as feasible, through "social distancing." This strategy is designed to slow the acceleration of new cases so the health care system - infrastructure, clinicians, and other staff - can adequately handle growing demand for services.

Social distancing also buys much-needed time for the state and local public health systems to prepare and scale up for a traditional public health outbreak response. However, it is important to recognize that "flattening the curve" through social distancing delays potential infections, but does not necessarily prevent them from occurring or causing serious complications, barring the availability of a new vaccine, the emergence of new and effective therapeutics, or a spontaneous change in the virus. Thus, handling the demand for healthcare services is just one policy goal: minimizing infections, hospitalizations, mortality, and economic and social disruption are a partial list of the multiple goals state leaders need to balance.

In response to the COVID-19 outbreak, North Carolina took early action to encourage and then order statewide social distancing.[2] While not enough time has elapsed to perform a rigorous empirical evaluation of these policies, we have seen practical evidence that the public is effectively practicing social distancing. For example, anonymized, consolidated cell phone movement data can approximate the degree to which the population in a given geography has changed their aggregate daily distance traveled.[3]

Exhibit 1 Change over time in the 'mobility index' in North Carolina.[4] This index measures the average distance traveled divided by the 'typical' distance traveled for a location times 100. Index values above 100 indicate increased travel, and values below 100 indicate decreased travel.



[1] The authors of this brief are also participants in the COVID-19 research collaborative.
[2] North Carolina Department of Health and Human Services, Division of Public Health. Coronavirus Disease 2019 (COVID-19) Response in North Carolina: Executive Orders. Accessed April 15, 2020.
[3] Mobility data provided by Descartes Labs under a Creative Commons Attribution 4.0 International License. These data are released at the state & county level from an analysis of a commercially available dataset of device geolocation information, and are statistically aggregated. No single device can be traced; only the population average total distance traveled per day is used as a proxy of activity.
[4] Warren, MS and Skillman, SW. Mobility Changes in Response to COVID-19. arXiv:2003.14228 [cs.SI], March 2020.

Researchers can review these data at the regional or county levels as various policies are enacted to track general, average, non-person-specific population movements over time. Given that a core factor in explaining the rate at which a virus spreads is physical proximity among people, we infer from preliminary observation of these and other data that North Carolinians are practicing social distancing that may have slowed transmission of the virus.

We can also measure progress more directly. We can see evidence that diagnosed case doubling rates have slowed, from a doubling time of 2 days at the beginning of the epidemic, to a doubling time of greater than 5 days by the end of March, to today's doubling time that is greater than 10 days. Importantly, however, note that here we are referring to doubling rates of confirmed (diagnosed) cases, which is a function of testing capacity and strategy; we do not know the doubling rate for all (including undiagnosed) cases due to limited testing.

To be sure, the virus continues to spread even with social distancing policies in place. Using a new short-term forecasting method,[5] we project that, as of analysis on April 16, the statewide diagnosed case count is likely to grow from 5,123 (the April 16 current total) to about 7,300 over the next week (that is, by April 23), with an uncertainty interval to the projection of 5,500 to 9,840. Despite continued growth in diagnosed cases and the underlying infection rate of COVID-19, North Carolina's early response of enacting social distancing policies and the public's response to them has likely helped the state to avert worst-case scenarios that could have happened in the absence of effective intervention.

The question now is, "how do we transition from where we are now into a next phase, and how can this transition be guided by data?" As we describe below, this transition plan must ensure that we remain vigilant to suppress viral transmission and discourage significant spread of COVID-19 in the interest of both public health and the economy.

In this brief, we elaborate further on the implications of our recent work and describe one approach we are using to monitor COVID-19-related hospitalizations based on near-term forecasts and current "hard information" from hospitals regarding their actual current census and remaining capacity.

What modeling tells us about the next stage of the COVID-19 response in NC

Modeling the longer-term effects of a new viral disease like COVID-19 is particularly challenging, especially with incomplete and often changing data. But like peering through a periscope, modeling can reveal something about the basic contours of the terrain before us to guide the journey ahead. Modeling can also help us avoid making costly mistakes. In that spirit, we review the implications of our April 6 forecasts, which we plan to update in the near future.

In our April 6 report, we examined the potential for an influx of demand from COVID-19 patients to surpass available bed supply in the state's hospitals. We explored two divergent policy scenarios.

- **Scenario 1, "Maintain"**
  Policies consistent with the current assumed effectiveness of the stay-at-home order and related population movement practices will remain in place indefinitely to maintain the control spread of the virus.
- **Scenario 2, "Lift"**
  After the current stay-at-home order is lifted on April 29, all social distancing policies and practices resort to pre-COVID-19 emergence levels.

[5] Our approach to near-term forecasting is adapted from the literature on synthetic controls. The synthetic control method, as described in Abadie et al. 2010, is an approach to estimating and predicting the effects of events or policies that take place at an aggregate level and the impacts of which are measured in aggregate entities such as countries or states. We create a synthetic version of North Carolina composed of countries that have had earlier COVID-19 outbreaks statistically weighting selected countries to match the history of confirmed cases in NC thus far and then further weighted by the ratio of the location's total population to the total population of North Carolina.

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We asked, in essence, "what happens if we flip a switch and go back to life as normal?" We found that quickly shifting away from current social distancing policies and practices ("Maintain") to immediately lifting all such policies starting in late April/early May ("Lift") would roughly double the likelihood that demand for services would outstrip supply. Based on the information we have today, as reported in our April 6 brief, we believe "flipping the switch" to fully re-open at the end of the month may impede our healthcare system's ability to to effectively treat COVID-19 patients and others.

On the other hand, the "Maintain" scenario has its own sets of significant challenges. A prolonged period of maximum social distancing over the long term has significant economic and social costs, in addition to the possibility of exacerbating some negative health effects, especially when coupled with economic anxiety. As quickly as feasible, people will need to get back to work, schools will eventually need to re-open, and people will need to regain mobility. Just as flipping the switch and reopening fully and immediately is infeasible, maintaining the current status quo for an extensively prolonged period is also infeasible.

Where do we go from here?

Reopening the state using a "dimmer switch"

The approach we propose for reopening the state is akin to a "dimmer switch," not an "on-off switch." A dimmer switch approach is designed to maintain manageable levels of viral transmission while the state calibrates and implements a staged reopening.

Between the two extremes of "Maintain" and "Lift" in our preceding analysis, our model results help us lay the groundwork for the planned relaxing of restrictions on movement and work while also strongly encouraging various ongoing social distancing practices.

The next phase in our state's COVID-19 response requires:

1. Planning for and executing a set of gradual reopening policies and milestones that allow people to safely get back to work while maintaining and further reducing levels of viral transmission.

   As illustrative examples, the state could stage reopening strategies geographically based on the latest available data, or among particular demographic groups (e.g., vulnerable populations remaining under stay-at-home instructions), or in other ways (e.g., encouraging companies whose employees can work remotely effectively to do so while finding ways to allow companies and workers who require physical proximity to do so in a manner consistent with social distancing where possible). Again, these are merely hypothetical examples of "dimmer switch" strategies proposed in other jurisdictions and do not reflect the views of our employers nor of any agencies.

2. Improving and expanding existing surveillance systems to detect viral hotspots and outbreaks that require increased public health response.

3. Increasing testing capacity, protective equipment inventory, and the contact tracing workforce as robust elements of a larger reopening strategy.

All of the above strategies must work together. For example, under any reopening scenario, we must have the availability of fast, widespread testing and rapid contact tracing to manage any outbreaks that emerge as people come back into more frequent contact with one another. Vigilance will be key to keeping outbreaks from quickly overwhelming an area.

These steps will enable a "dimmer switch" approach to reopen the state and put people back to work at an appropriate pace. It will also facilitate carefully monitoring transmission rates and hospital and healthcare workforce capacity so that reopening adjustments can be made in the interest of public health. In practice, the state likely needs a set of multiple dimmer switches -- not a single policy approach for the whole population but varying approaches for different populations or geographies.

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There are a number of other emerging national proposals for containing the virus and gradually reopening the economy that are complementary to our proposed dimmer switch approach. See A National COVID-19 Surveillance System: Achieving Containment;[6] A National and State Plan to End the Coronavirus Crisis;[7] and National Coronavirus Response: A Road Map to Reopening.[8] The White House yesterday released a proposal that also appears conceptually related to the dimmer switch approach. Each of these proposals outlines a similar strategy of reopening in stages with increasing data surveillance and other capacity to guide the pace.

As North Carolina leaders adapt such proposals here, the "dimmer switch" approach we have laid out represents the likely "new normal" for our state for the foreseeable future. We need to prepare for COVID-19 to be part of our lives for a long time, and even as we reopen, we need to embrace prolonged or intermittent social distancing to protect both public health and the economy.

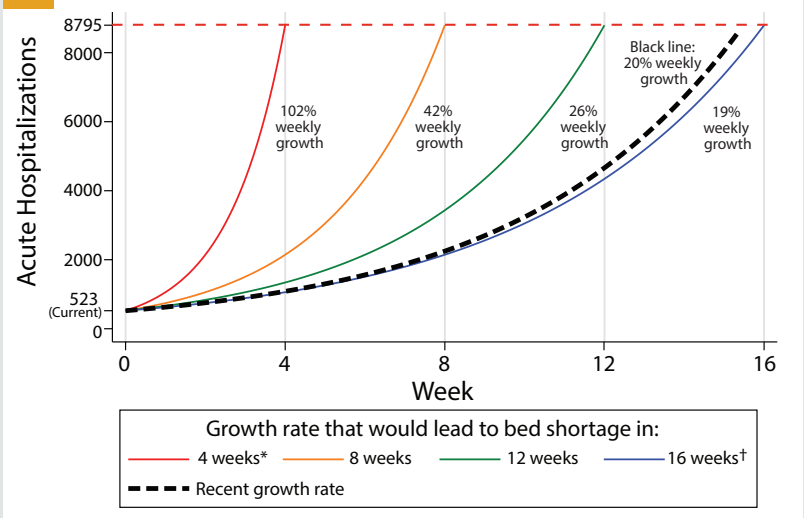
Adjusting the dimmer switch: how rapidly can we reopen?

In this section, we offer a quantitative framework for influencing how rapidly or aggressively we can "turn" the dimmer switch and move toward reopening. This particular approach is oriented to identifying the COVID-19-related hospitalization growth rate that the state's healthcare systems and health care workforce can effectively manage over the next few months.

We demonstrate our framework using statewide acute beds, but the approach could also be applied to ICUs or ventilators, and it could potentially be applied at a regional level as well. As a caveat, we acknowledge that this particular approach is centered on only one outcome: avoiding a too-rapid influx of patients into our emergency departments and hospitals that overwhelms our health care workforce. In practice, North Carolina's leaders and citizens must weigh multiple important goals simultaneously (e.g., reducing overall morbidity and mortality, protecting healthcare workers, mitigating economic harms, addressing disparities, and others). Furthermore, most of the discussion here refers to "beds" as the limited resource, but we expect a healthy, qualified staff supporting those beds to be in shorter supply.

This current day situation is illustrated in Exhibit 2, below. As of April 15, 2020, there were approximately 8,795 beds available statewide to manage COVID-19 patients, and there were 523 COVID-19 patients currently hospitalized (see Y-axis).[9] The black curve in the graph assumes the recent weekly hospitalization growth rate of approximately 20% is maintained into the near future from the current starting place of 523 hospitalized COVID-19 patients. From the starting point of today's 523 patients, the X-axis shows the number of weeks that would elapse before the total number of hospitalized patients reaches the aggregate (current) hospital capacity of 8,795 beds at the current growth rate. At a faster growth rate, it would take less time to reach peak capacity, as illustrated by the curves to the left of the black (20% growth rate) curve.

Exhibit 2 Present day: hospitalization growth rates and time needed to hit hospital capacity limit



* To hit capacity in 4 weeks would require a weekly growth rate of 102%, much higher than the recent weekly growth of 20% shown in black. † To hit capacity in 16 weeks would require a weekly growth rate of 19.2%, about the same as the recent weekly growth of 20% shown in black.

[6] Mark McClellan, Scott Gottlieb, Farzad Mostashari, Caitlin Rivers, and Lauren Silvis. American Enterprise Institute. March 28, 2020.
[7] Zeke Emanuel, Neera Tanden, Topher Spiro, Adam Conner, Kevin DeGood, Erin Simpson, Nicole Rapfogel, and Maura Calsyn. Center for American Progress. April 3, 2020.
[8] Scott Gottlieb, Caitlin Rivers, Mark McClellan, Lauren Silvis, and Crystal Watson. Duke-Margolis Center for Health Policy. April 7, 2020. [9] Source: NCDHHS adjusted for hospital non-response

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Given current numbers as of April 15, the growth rate necessary to breach current capacity within 4 weeks would be a ~102% weekly growth rate (red curve), calculated: $523 * (1+102\%)^4 = 8795$, considerably higher than the recent weekly trend of around a 20% weekly growth rate (black curve).

This quantitative framework suggests it is quite unlikely we would see the kind of growth necessary to put our healthcare system in serious crisis within 4 weeks from today if policies in place stay roughly the same.

But note that the possibility of demand exceeding supply is still possible at the present 20% weekly growth rate over 15-16 weeks (or at an even slower growth rate over slightly longer, as depicted by the blue curve to the right of the black curve).

If these trends hold, once we have crucial outbreak containment activities at adequate levels (including rapid testing and tracing capabilities), we could potentially explore a modest reopening strategy which is unlikely to severely pressure the hospital system in the very near term (i.e., the next few weeks).

Using this short-term forecasting method, we can keep a watchful eye on all of these metrics: current census, currently available capacity, growth rates, and near-term forecasts based on recent data, to guide reopening strategies.

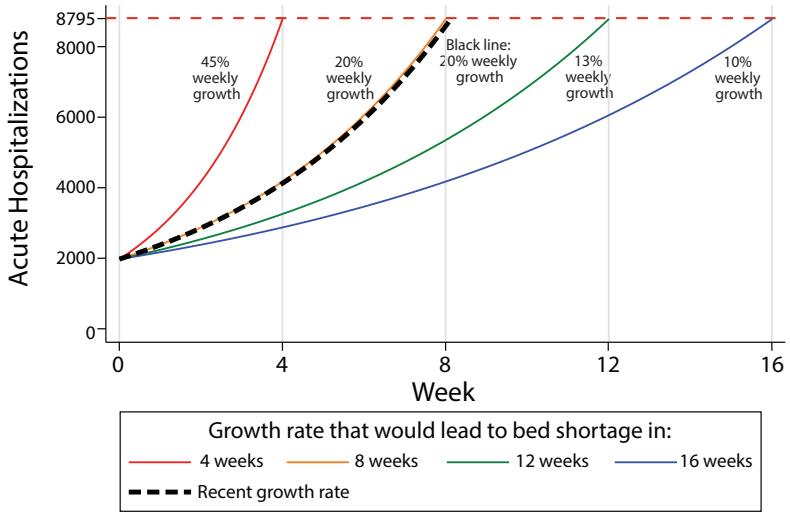
However, it would be a mistake to conclude that current slack in the hospital capacity should lead us to a full and hasty reopening in the near term. A virus like the one that causes COVID-19 can spread quickly, causing many more infections and subsequent hospitalizations than might initially be anticipated.

For example, fast forward a few weeks, and imagine social distancing measures were relaxed, and the number of COVID-19 patients hospitalized has now risen to 2,000 statewide (again, this is hypothetical, not the result of new modeling).

This could occur within a relatively compressed time period (e.g., a few weeks) if the hospitalization doubling rate were to rise due to increased social contact, to, hypothetically, a rate that resulted in something like a hospitalization doubling time of a week, which could take the COVID-19 hospitalization figure, for example, from the present-day 523 patients to 1,000 patients after one week, and then to 2,000 patients after two weeks.

Exhibit 3 below illustrates the previously-described scenario that could be caused by a hypothetical - but not impossible - significantly increased level of viral spread in the near term, under a potential hypothetical "too quick on the dimmer switch" reopening. Let's suppose that as we approach the hypothetical 2,000 hospitalization threshold, social distancing measures are reinstated, and we returned to approximately a 20% weekly growth rate in hospitalizations.

Exhibit 3 Hypothetical future example: illustrative growth rates and times to hit hospital capacity limit



In this future scenario, the black line depicts a 20 percent weekly growth rate continuing over the next several weeks after hitting 2,000 hospitalizations. As you can see, under that scenario, demand would reach or exceed supply (red horizontal line) in just eight weeks if that (20%) weekly growth rate continues. Other (faster and slower) growth curves are also shown that would each reach or exceed hospital capacity over various time periods. In this scenario, policymakers would need to consider further measures to slow the growth rate and reduce the number of people hospitalized in order to increase the likelihood the system could meet the demand -- a "dimming the lights down" intervention.

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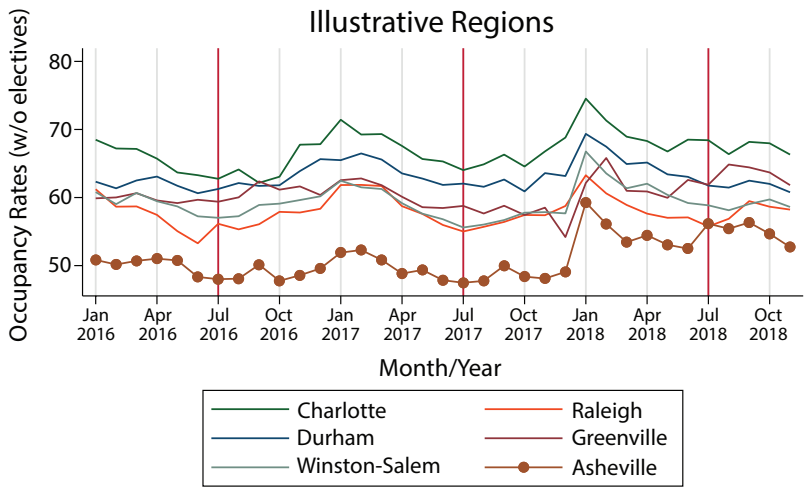
Acknowledging again that healthcare capacity is just one factor guiding the state's reopening, this illustrates a use of the "dimmer switch" approach to reopening while keeping a careful eye on hospital and healthcare workforce capacity. We could use this approach along with other forecasting and surveillance strategies to inform how aggressively to "turn" the "dimmer switch" from the current position of statewide stay-at-home orders toward eventual reopening.

The following caveats remind us of the importance of caution as we adjust the dimmer switch through policy.

- Instituting reopening policies (turning the dimmer switch) will likely increase infection rates, but the effects of a given change in policy will be lagged, not instantly detectable. Hence, we need to build in time after making significant policy adjustments to allow for updated forecasts to guide next steps.
- This epidemic is likely to have *multiple* peaks. In recent days, the number of new cases in North Carolina has appeared to plateau, leading to some speculation that we may be near "the" peak. But nearly every model of infection dynamics expects a release of social distancing measures to increase the infection rate and thus an increase in diagnosed cases. Turning the dimmer switch conservatively will help us manage the peaks.
- Policies can also be used to control the timing of peaks. In North Carolina, hospital occupancy rates vary by roughly 5 percentage points from the high in January to the low in July. Exhibit 4 shows the (pre-COVID-19) seasonal variation in the percentage of occupied staffed beds (not including normal newborns or elective cases). In any given year, there are roughly 1,000 more beds available in July than there are in January, so peaks occurring in the summer are less likely to exceed the capacity of the healthcare system. Note that the occupancy rates also vary across the state; the Asheville region, for example, typically has proportionally more available beds than the Charlotte region. All other things equal, epidemic peaks that occur differentially across the state will better enable the healthcare system to respond than a statewide peak that occurs throughout the state during the same time period.

Exhibit 4 **Hospital Occupancy Rates 2016-2018**



Electives and normal newborns omitted.
Dec 2018 omitted due to incomplete discharge data.
Data Source: North Carolina Hospital Discharge Data, Sheps Center, University of North Carolina.

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Key Takeaways

1. In the early stage of the COVID-19 pandemic, aggressive social distancing policies have likely bought us time, protected our hospitals and healthcare workers, and kept more people safe compared to an alternative scenario in which social distancing policies had not been put in place or were enacted much later.
2. Reopening fully and hastily by relaxing all social distancing policies prematurely would markedly increase the probability that hospitals and healthcare workers could face an unsustainable influx of patients in a compressed time period.
3. However, it is likely also infeasible to remain under universally aggressive social distancing policies indefinitely, as such measures also carry their own substantial consequences and costs.
4. We propose a gradual, "dimmer switch" approach to reopening. Core elements of the reopening plan must include proven outbreak containment activities, such as rapid testing and contact tracing along with careful monitoring of hospital capacity and the safety and supply of our healthcare workforce.
5. As we've shown here, the pace and timing of the reopening plan should be informed in part by near-term forecasts projecting impacts on hospital capacity and augmented by longer-term forecasts from traditional epidemiological models.
6. The reopening process should include appropriate observation time to assess effects of actions before further "adjustment of the dimmer switch." This underscores that the "new normal" is one in which COVID-19 and society's responses to it will be part of our lives for a long time, and that, even as we reopen, we need to embrace social distancing practices to protect both public health and the economy.
7. Finally, reopening can be calibrated with technical strategies (such as those we describe here) to avoid exceeding hospital capacity, but in the end, any chosen strategy is a set of complex tradeoffs with profound ethical and social consequences. The only true long-term solution is to fully eradicate the virus or to develop a broadly effective and safe treatment for the disease it causes.

Graphic design: Colleen Barclay, MPH