

STOPPING COVID-19:

SHORT-TERM ACTIONS FOR LONG-TERM IMPACT

MARCH 2020

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MITRE's mission-driven teams are dedicated to solving problems for a safer world. Through our public-private partnerships and federally funded R&D centers, we work across government and in partnership with industry to tackle challenges to the safety, stability, and well-being of our nation.

This memo is put together by MITRE's infectious disease analytics team, which projected the trajectory and consequences of the Ebola outbreak, as well as other epidemiological events. We base our recommendations on quantitative analysis and modeling developed for prior epidemics, yet tailored and advanced for COVID-19.

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- The COVID-19 pandemic presents an imminent and severe threat to the lives of our citizens, the American healthcare system, and the economy. The purpose of this paper is to recommend **measures that U.S. leaders can and should take right now to limit the course of COVID-19.**
 - **National, state, and local leaders can and must institute significant social distancing** through Non-Pharmaceutical Interventions (NPIs) in order to reduce the spread of COVID-19.
 - We believe that we need to **reduce the human-to-human contact rate of Americans by 90 percent** to stop this epidemic.
 - The emergency policies outlined in this brief are essential for the health and economic security of U.S. citizens. While they may appear painful, costly, and intrusive, these measures are critically important to suppress, and eventually eliminate, the spread of COVID-19 among Americans.

WHY IS AGGRESSIVE AND MULTI-FACETED SOCIAL DISTANCING CRITICAL RIGHT NOW?

Without social distancing, the rapidly escalating COVID-19 infection rate in the United States will result in significant morbidity and mortality for a large percentage of American citizens within months. As of March 18, 2020, there were more than 7,600 confirmed infections in the United States. The rate of increase in domestic cases (which varies somewhat from day-to-day depending upon how you measure) is now estimated to be in the range of 25 to 40 percent per day near to or eclipsing the alarming rates of case growth occurring in France and Italy, where governments have recently instituted strict social distancing actions to prevent further transmission. Our work suggests that without significant social distancing in the United States, the COVID-19 virus could infect millions within months.

We believe that U.S. case counts are likely underrepresented due to an inadequate domestic testing infrastructure; further, as testing accelerates, the number of confirmed cases will jump.

Some efforts at social distancing are taking place in the form of select state-wide school closings and the cancellation of large events; the federal government has suspended air travel from many countries where COVID-19 is spreading.

While many NPIs are in place locally, the challenge going forward is to make such measures widespread, intensive, and consistent across the country. It's important to note that due to the limited testing capabilities and long duration of asymptomatic infection, existing scattered and inconsistent NPI policies will not be sufficient to curb the spread of COVID-19. The United States needs to implement a more impactful and coordinated set of actions to 1) significantly reduce the contact rate across the U.S. population in order to slow and eventually eliminate COVID-19 in the U.S., and 2) suppress a later resurgence of COVID-19.

While the challenges seem overwhelming, Hong Kong, Singapore, and other nations and jurisdictions have taken proactive actions that have successfully limited the velocity of transmission among their population. However, they acted after very few cases emerged in or around their borders. We already have thousands of confirmed cases in the United States and likely far more unconfirmed, so we will, in all likelihood, have to do much more than Singapore and Hong Kong to suppress case expansion.

This document outlines the risks of COVID-19 domestically and illustrates that the contact rate across the U.S. population needs to be significantly reduced—by as much as 90 percent—to contain this epidemic. We offer an ordered list of measures that federal, state, and local leaders can and should enact in a widespread and synchronized manner to stop the spread of COVID-19. Separate and more extensive analyses that support the assertions and results presented in this document exist and are available.

THE IMPERATIVE

COVID-19 has an observed reproduction number and mortality rate similar to those estimated for the Spanish Flu of 1918.

There is debate as to the exact observed reproduction number and the case fatality rate of COVID-19, but in combination, published estimates point to an epidemic that is approximately as dangerous as the Spanish Flu that infected 500 million people and killed 50 million worldwide. That flu resulted in 675,000 deaths in the United States alone. At the time, the world's population was only 1.8 billion, and the U.S. population was 103 million. While the scientific community has evolved its ability to care for patients over the last century, we are living in a world with a much higher rate of population mobility and travel flows. We believe that already implemented and expected social distancing actions, although scattered and inconsistent both within the United States and abroad, will have a beneficial impact on the propagation of the virus. But, it is difficult to ascertain to what degree. As such, we should be cautious not to extrapolate from the outcomes of the Spanish Flu.

The analyses presented here are based on reported and confirmed cases, which we believe significantly underrepresent the actual number of active domestic COVID-19 infections. We believe that COVID-19 cases are currently underrepresented in large part due to our current limited testing capability and the multi-day period of asymptomatic infectivity associated with the COVID-19 pathogen.

The case fatality rate (CFR) for COVID-19 is estimated to be in the range of a half percent to greater than one percent of those infected. CFR is notoriously difficult to compute because of the latency between exposure, illness, and death, along with the aforementioned difficulty of case confirmation. To get a truly accurate CFR, estimates require a comprehensive case confirmation infrastructure and the ability to track individual patient outcomes, both of which have been challenging in the current environment. Based on the current velocity of COVID-19 progression in the United States, the CFR in the range above would mean thousands to tens of thousands of fatalities domestically and an unbearable strain on our healthcare system within a very short time. Such a scenario would tax our ability to care for both COVID-19 and other patients and would come with significant accompanying damage to our economic security.

POLICY OPTIONS TO SLOW AND STOP COVID-19

Pharmaceutical solutions, including vaccines and treatments for COVID-19, have been reported to take 12-18 months to develop. In the interim, we must slow the pace of infection, through the widespread implementation of social distancing actions. To truly suppress the progression of COVID-19, which is propagated through person-to-person transmission, the U.S. population's contact rate must be significantly reduced through mobility restrictions and other means of social distancing. These measures include restricting domestic and international travel, encouraging the closure of certain businesses, incenting work-at-home policies, closing schools and universities, canceling concerts and sporting events, limiting numbers in restaurants and other social gathering places, and, in extreme situations, incentivizing quarantine-related actions. **We estimate that we will have to reduce the human-to-human contact rate of our citizens by approximately 90 percent to successfully suppress COVID-19.**

IMMEDIATE ACTION IS REQUIRED

The temptation for many government leaders is to delay the implementation of aggressive social distancing measures in order to minimize economic costs and social disruption. Such an approach is fundamentally short-sighted and dangerous. Despite hesitation on the part of many government entities, many of the largest corporations in the United States have implemented voluntary and significant social distancing actions.

The progression of infections in Singapore and Hong Kong, where moderate social distancing measures were enacted very early in the epidemic, occurred much more slowly compared to progression rates in Italy and Iran, both of which waited to enact NPI measures. Late NPI measures forced Italy to enact highly disruptive and draconian quarantine actions, and the results are yet to be seen.

The velocity of an outbreak in a specific region is characterized by a construct known as doubling time. This value describes the number of days, on average, required for the number of cases to double in a given area. This measure can describe disease behavior worldwide, in a country, or even in a smaller region such as a state. For our purposes, we will discuss doubling time at a national level.

Below, we have calculated doubling time for several nations, on a trailing, rolling 10-day basis, based on March 14 case values. A decline in doubling time indicates that the infection rate is accelerating (cases double in fewer days), while an increase of doubling time indicates that the regional infection rate is slowing. Ideally, when NPIs are implemented aggressively in a region and after some period of delay, doubling times should begin to increase in a matter of days, weeks, or months, depending upon the severity of the local epidemic and the degree of social distancing prescribed by the NPIs. Given the number of NPIs already being enacted or implemented across the country, one should be cautious not to extrapolate growth rates from trailing statistics.

Table 1 shows the current 10-day lagging doubling times for COVID-19 for several countries.

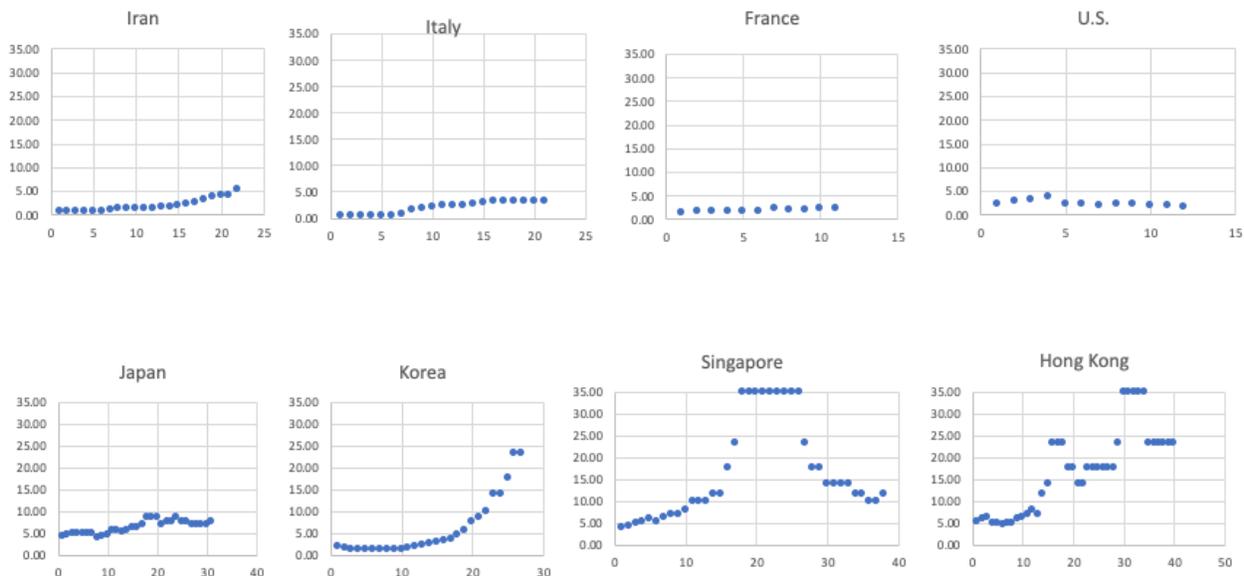
Table 1: 10-Day Lagging Doubling Times for COVID-19 for Eight Countries (March 12)

Country	South Korea	Singapore	Japan	Hong Kong	Iran	Italy	France	United States
Doubling Time (days)	23.33	11.61	7.78	23.33	5.38	3.18	2.33	1.75

As depicted in the following graphs, doubling time increased rapidly in both Singapore and Hong Kong, when these countries implemented a set of NPIs early on.

The United States continues to show a very short doubling time with no improvement to date, due to what we believe are spotty and not well-coordinated social distancing actions. However, these values are very sensitive to starting assumptions and are trailing statistics, and should not be used to extrapolate forward values. In addition, the many NPIs being implemented around the country in recent days should, over time, have some beneficial impact on doubling times in the United States.

Figure 2: Derived Rolling 10-Day Average Doubling Rates for Seven Countries and Hong Kong



It is important to understand that Singapore's recent decline in doubling time, which can be observed in the graph above, is due to the "importation of cases" to Singapore from Indonesia and Europe versus a failure of implemented NPIs. The very low case counts in Singapore exaggerate this effect on doubling times from these imported cases.

WHY ACT NOW?

As measured on March 12, on a trailing basis, the United States showed the worst doubling time among the nations we've observed. We are well past keeping the virus out of the country and must focus resources on limiting community transmission. In contrast, Hong Kong and Singapore acted so early they were able to focus largely on containment.

These lessons learned from other regions as well as our modeling of this and other pandemics support the implementation of early and proactive NPIs. We believe that the time to activate NPIs at a state level is not when significant cases have already appeared. Rather, **implementation should occur at the sign of the first infection** or earlier if a significant infection rate exists in neighboring states.

Moreover, as more individuals become infected, the **strains on the U.S. healthcare delivery system will be significant**. Because it typically operates at very thin margins, commercial medical delivery operations tend to run with little to no slack capacity. Hospitals generally have few or no empty beds and are staffed with precisely the number of professionals needed to meet normal demand.

As cases of COVID-19 increase, additional testing and patient care will be needed, shifting the focus of many medical professionals away from their normal duties. This, in turn, will impact the

many non-COVID-19 patients. However, the real stress on our healthcare system will derive from the significant resources required to treat severely ill coronavirus patients. Caring for the very ill COVID-19 population requires regular and intensive care hospital beds, medical staff, protective gear, and many other resources. An additional risk is that many healthcare workers will themselves become infected, reducing the resources to care for coronavirus patients.

One key resource is our limited supply of mechanical ventilators. Most experts today agree that **the most severely ill coronavirus patients** (estimates of the number of COVID-19 patients who will need ventilators range from two percent to six percent) **will require this medical device** until they recover or pass away (currently estimated to be ten to fourteen days). Even utilizing all existing ventilators, the United States would be unable to care for all critically ill COVID-19 patients if the number of active case counts surges significantly. In such a scenario, decisions would have to be made as to which critically ill patients will receive the ventilators and which will not.

A RECOMMENDED SEQUENCE OF ACTIONS FOR THE NATION

Our models indicate that defeating the COVID-19 outbreak in the United States will require that our citizens reduce their contact rate with other citizens by 90 percent. The following is a recommended set of actions. Each of the directives regarding specific social distancing actions, if implemented widely within the United States, will individually lower the contact rate of our populace by some percentage. However, it is unlikely that the implementation of a subset of these recommended measures will get us to the 90 percent contact rate reduction that we need. In short, we believe that all or a very large percentage of the recommended NPIs must be implemented simultaneously across the entire United States. If these measures are not implemented broadly and consistently across the country, we will not reach the contact rate reduction target required to defeat COVID-19. As such, we strongly recommend that the federal government direct or mandate that the states implement these actions.

The recommended social distancing measures may have to be aggressively enforced to ensure compliance by the majority of the populace. Once these measures have been implemented broadly across the United States with accompanying enforcement, our analyses indicate that the country should experience significant slowing of the infection rate within a few months. It is important to note that our estimate of the necessary contact rate required to defeat COVID-19 may vary as we get a better understanding of the number of *actual* cases in the United States.

It's important to remember that regardless of these interventions, the case counts in the United States will likely jump in the near-term, largely due to an upcoming increase in testing capability.

Specific recommendations:

1. Immediately close all schools and institutions of learning in the United States regardless of location (move to remote learning where possible).
2. Incentivize private enterprises to implement remote work policies and ensure social distancing is maximized in operating facilities.
3. Support and encourage commercial food, medical, and basic supply distribution businesses to remain in operation as well as related transport and logistics operations.

- Have the government ensure a sanitary environment for the production and delivery of materials and protect employees of these entities with testing and protective gear.
4. Shut down places of social gathering, including restaurants, bars, movie theaters, concerts, sporting events, etc.
 5. Extend the Centers for Disease Control and Prevention recommendation to build home food supplies to everyone, not just the elderly. Provide financial support and food to those who cannot afford or are otherwise unable to do so.
 6. Seal or restrict all U.S. borders to all forms of traffic/transport, after allowing a week for Americans to return home if they desire.
 7. Depending upon the number of cases in a country from which an American is returning, quarantine returning citizens in hotels or other facilities, one to a room, with skeleton staff (also protected). Ensure these facilities are supplied with food, water, and communication capabilities, compensating the facility providers with federal monies.
 8. Incentivize Americans not to leave their home for anything other than medically necessary movement or to work in support of other NPIs and U.S. critical infrastructure.
 9. Provide compensation (net-out payments to employees) to business owners for temporarily closing non-essential businesses that require major physical presence at their facilities to operate.
 10. Ensure that food, water, and medically necessary products and services delivery capabilities remain in place, or are extended as needed throughout the country, compensating providers appropriately.
 11. When the observed reproduction number drops sufficiently, until all new cases are under contact tracing (depends on existing level of infections, which have to be measured carefully and continuously), begin to gradually lift implemented NPIs (epidemics die off quickly when observed reproduction rates drop well below 1). Once there are no new cases for at least one week, we can begin to lift NPIs. We must be extremely vigilant and thorough with our testing in order not to stop social distancing actions too early, or we may face a resurgence of the epidemic. We anticipate the NPIs will have to remain in place for at least three months.
 12. Diligently monitor for residual infections and aggressively quarantine families of new patients for three weeks, providing basic services as needed. Provide consistent supports for those families during the quarantine period.
 13. Do not unseal borders until the global pandemic is under control.
 14. Prepare for resurgence and watch case counts for signals that a second wave of actions is needed. Make sure there is a widespread surveillance and testing capability in place to detect and monitor infections.

CONCLUSION

The social distancing and related NPIs we've recommended are necessary to slow the infection rate of this epidemic to a point of eventual elimination. Doing so will preserve the health and economic security of our nation and minimize morbidity and mortality for our citizens. Once such a path of actions is laid out and broadly and clearly communicated to our citizens, and a few weeks of case progression slowing is observed and also communicated broadly, our citizens will

understand the trajectory of the epidemic and its likely end. These actions should provide encouragement for Americans and should calm capital markets, as at least the duration of the epidemic will be better understood, and a logical process communicated as to how we will get past it as well as continuing indications of how we are progressing.

Reference materials are available upon request.