



# Risk and resilience in the time of the COVID-19 crisis

Benjamin D. Trump<sup>1</sup> · Igor Linkov<sup>1</sup>

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The novel coronavirus (COVID-19) has had an undeniable impact upon global societies, public health, and economies. Local spread of the virus has reached nearly all countries and territories, with billions under varying states of lockdown and crisis response. Though the world will be permanently altered by the direct and indirect impacts of COVID-19, considerable uncertainty surrounds the various future paths available to us as we seek to mitigate further outbreaks while reopening various economic and social activities over time.

Even at the earliest stages of crisis response, it is clear that the policy decisions adopted in the near term will directly influence the capacity for a region's recovery, with some using the disruption of COVID-19 to adapt and 'bounce forward,' while others potentially far worse off for the foreseeable future (Trump et al. 2020a, b). With so much uncertainty surrounding COVID-19, there is a considerable need for lessons, allegories, and scientific insight from all fields of study. Decision-makers require trusted and holistic data sources to draw policy conclusions, while broader society requires clearly communicated messages for reassurance, instruction, and generally improved morale (Merad and Trump 2020).

Complicating matters is the long-term nature of this pandemic challenge. While most crises or disasters are constrained within a relatively limited space and time, pandemics persist and reverberate for months or even years—forcing health workers, emergency responders, analysts, and various other critical workers to operate with extended hours and considerable stress under an extended period. Amidst the crisis, governments, companies, and broader civil society will be asked to execute work and facilitate pandemic response and recovery in a collective effort. The enormity of such a challenge cannot be understated. Building resilience (i.e., ability to respond, recover and adapt to disruption,

Linkov and Trump 2019) is of crucial importance in overcoming this and future pandemics.

Whereas many pandemics have had later recurrence (e.g., 'waves' and 'peaks'), this crisis-focused environment will likely continue through the end of 2020, and even beyond. This means not only will key stakeholders need to resume crisis response work at some uncertain date, but that they may have to do so under even more challenging circumstances than were observed in Winter and Spring 2020. The potential for an outbreak to co-occur with another crisis, such as a tropical storm, earthquake, or wildfire, could dramatically complicate emergency response efforts on one hand, and efforts by broader society to comply with guidance regarding pandemic mitigation on the other. Though it is impossible to predict where, when, or even whether such a compounding crisis may occur, it is essential to generate best practices and analytical support now to prevent an unmitigated disaster from destroying a community or region.

This special issue is our attempt to gather early ideas and results from application of risk and resilience analytics to the COVID-19 pandemic. Tackling a portion of the broader issues facing the current and future challenges of COVID-19, the pieces discussed below provide unique perspectives on how stakeholders and decision-makers can better understand the systemic and sweeping nature of COVID-19 disruption, as well as what types of interventions might be tested and deployed to maximize socioeconomic and public health recovery and adaptation over the extended future.

## 1 Introducing *environment systems and decisions'* special issue on COVID-19

This special issue includes a diverse array of perspectives on COVID-19, with particular emphasis regarding pandemic risk assessment, mitigation, recovery, and adaptation. Drawing from disciplines ranging from comparative historical analysis to civil and environmental engineering, the papers in this issue present a holistic analysis of how to interpret the policy actions and ensuing consequences of COVID-19,

✉ Benjamin D. Trump  
Benjamin.D.Trump@usace.army.mil

<sup>1</sup> US Army Corps of Engineers, Engineering Research and Development Center, Concord, MA, USA

as well as how to onboard resilience and systemic capacity for recovery as a core necessity even at the earliest stages of pandemic response. Comparative analysis herein draws from cases the world over, including the European Union, United States, Africa, Asia, and Australia. While no single solution can alleviate the broad array of challenges that modern civilization currently faces, we believe that the pieces reflected here offer critical stories, anecdotes, and scientific guidance that will improve public understanding and policy-maker decision making in public health, economic, energy, and social systems.

Haldon et al. (2020) delve into historical cases, including the 6th Century Plague of Justinian (Eastern Roman Empire), the 14th Century Black Death, as well as the series of sociopolitical feedback loops that hindered recovery within an Ottoman Empire beset by various maladies, war, and famine. In this, the authors provide a rich narrative of the costs, benefits, and requirements of pursuing resilience during and after significant existential challenge to the state's survival. Haldon et al.'s contribution provides a lens upon our modern predicament with COVID-19 as we consider options available to promote recovery over the coming years, as well as how social elites navigate, manage, and intervene in such crises to uphold vested interests.

Santos (2020) provides a framing of the impact of containment, suppression, and mitigation measures on interdependent workforce sectors. With pharmaceutical interventions requiring substantial time and resources to develop, test, approve, and implement to society, nonpharmaceutical interventions to 'flatten the curve' are critical to assist immediate pandemic response. Santos further delves into discourse surrounding the notion of personal liberty versus public health—a debate of rising importance as COVID-19's initial wave waned for many countries.

Similarly, Quigley et al. (2020) draw comparative analysis from multiple jurisdictions to assess concurrent, cascading, and systemic crises, including Australia, Bangladesh, and China as cases. The notion of resilience against such complex events is paramount, where government and public systems alike are pushed well beyond their normal intended parameters and faced with a critical juncture—recover, or collapse. For COVID-19, the ongoing 'crisis of crises' where we have concurrent public health, economic, and energy crises is one that requires political care at all levels of geographic scale.

Ndiili (2020) applies comparable crisis response analysis to the ongoing economic fallout of COVID-19 facing Sub-Saharan Africa. Specifically, Ndiili notes that COVID is having and will continue to have a substantial impact upon international investment, economics, and trade—the implications of which are vast for the developing economies and industries across the diverse array of African nations. Ndiili provides analysis regarding the interaction between

economics, public health, environment, and social governance, and concludes that all are in jeopardy due to COVID disruption unless proactive and substantial action is taken to prevent permanent disruption and loss to complex economic networks within the region.

Menoni and Schwarze (2020) address the question of transitioning from response to recovery, including consideration of assessment, management, and communication of risk and uncertainty over time. Drawing from lessons from the US, European Union, and international organizations like the United Nations and World Health Organization, they frame various data requirements to facilitate more efficient recovery pathways within various potential future scenarios.

Jovanovic et al. (2020) review the notion of recovery for healthcare infrastructure through the lens of resilience—a notion of rising importance internationally. Specifically, Jovanovic et al. take a comparative focus across complex interconnected systems to determine the disruptions that emerging risks may yield to such interconnected and interdependent activities and societal functions. Through such analysis, they discuss tools, metrics, and standards such as the ISO 31050 as avenues to standardize our formulation and analysis of systemic resilience for COVID-19. Ultimately, they argue that this challenge is not one that will conclude soon, but requires deliberation and care as COVID's initial wave declines, and the possibility of future waves or disruptions arise later.

Hynes et al. (2020) provide an additional detailed analysis of resilience and systemic threats, where complex systemic behavior has generated a ripple effect worldwide that disrupts activities as diverse as public health, fossil fuels, international monetary policy, and economic behavior. Hynes et al. assert that the policy regime established in the aftermath of the Great Recession and International Financial Crisis will be reshaped in the coming months, with critical questions about how to realign economic systems, supply chains, and overall attitudes towards globalization and international cooperation. Providing an in-depth analysis of multiple examples of resilience, Hynes et al. conclude that international cooperation is needed to overcome the herculean policy challenges facing many countries in the near future, and that clear dialogue of risk, resilience, and securing exceedingly complex and fragile systems should be the forefront of such academic and policy discussion.

Further on the topic of resilience, Keenan (2020) offers a perspective on the reciprocal relationships between public and private sector resilience planning activities and the ongoing COVID responses in the U.S. Specifically reviewing complex systems within the built environment, Keenan notes that ongoing COVID disruption might yield positive impacts for future resilience designs, plans, and policies within housing and the built environment.

Golan et al. (2020) analyze supply chain modeling and resilience from a rich analysis of the peer reviewed literature. A critical disruption posed by COVID is the degradation or outright destruction of supply chains—particularly for those with (a) international nodes and links, or (b) those supply chains with nodes with considerable risk of spreading COVID due to on-the-ground conditions (e.g., significant close-quarter activity). Where much of society is powered and enhanced with increasingly complex supply chains, an understanding of their capacities and needs for resilience is one that will improve current response and future policy to ensure such functions are able to quickly recover amidst disruption.

Critical challenges remain regarding how societies and governments will absorb and respond to the ongoing threat of COVID-19 as well as what the nature of subsequent recovery looks like. A key consideration for each policy, activity, and system is how it shapes broader societal resilience to bounce back from the range of outcomes afflicting public health, economics, and general societal harmony and well-being, with few definitive solutions indicating a one-size-fits-most approach for hundreds of countries and thousands of local and municipal governments. We hope that this special issue provides useful and timely perspective on addressing challenges that our society faced today.

## References

- Golan M, Jernegan L, Linkov I (2020) Trends and applications of resilience analytics in supply chain modeling: systematic literature review in the context of COVID epidemics. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09777-w>
- Haldon J, Mordechai L, Eisenberg M, White S, Izdebski A (2020) Lessons from the past, policies for the future. Resilience and sustainability in past crises. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09778-9>
- Hynes W, Trump BD, Love P, Linkov I (2020) A resilience approach to dealing with Covid-19 and future systemic shocks. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09776-x>
- Jovanovic S, Klimek P, Schneider R, Øien K, Brown J, DiGennaro M, Yan L, Pfau V, Jelic M, Rosen T, Caillard B, Chakravarty S (2020) Assessing resilience of healthcare infrastructure exposed to COVID-19: emerging risks, resilience indicators and international standards. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09779-8>
- Keenan J (2020) COVID, resilience, and the built environment. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09773-0>
- Linkov I, Trump BD (2019) *The science and practice of resilience.* Springer, Amsterdam
- Menoni S, Schwarze R (2020) Recovery during a crisis: facing the challenges of risk assessment and mitigation of Covid 19 outbreak. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09775-y>
- Merad M, Trump BD (2020) *Expertise under scrutiny.* Springer, Cham
- Ndiili N (2020) Unprecedented economic attack on Sub-Saharan African economies; Coronavirus. How severe is the perceived slump? *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09780-1>
- Quigley M, Attanayake J, King A, Prideaux F (2020) A multi-hazards earth science perspective on the COVID-19 pandemic: the potential for concurrent and cascading crises. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09772-1>
- Santos J (2020) Reflections on the Impact of “Flatten the Curve” on Interdependent Workforce Sectors. *Environ Syst Decis.* <https://doi.org/10.1007/s10669-020-09774-z>
- Trump BD, Bridges T, Cegan J, Cibulsky S, Greer S, Jarman J, Lafferty B, Surette M, Linkov I (2020a) An analytical perspective on pandemic recovery. *Health Security.*
- Trump B, Keisler J, Volk K, Linkov I (2020b) Biosecurity demands resilience. *Environ Sci Technol* 54:4706–4708

Golan M, Jernegan L, Linkov I (2020) Trends and applications of resilience analytics in supply chain modeling: systematic literature