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Resilience

Directions for an Uncertain Future Following the COVID-19 Pandemic

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April 2025

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Final Report

Prepared for US Army Corps of Engineers
Washington, DC 20314-1000

Under Funded in parts by the US Army Corp of Engineers Military Funding Program
FLEX on Resilience and Compounding Threats

Abstract

The concept of resilience is multi-faceted. This commentary builds upon the analytical distinctions of resilience provided by Urquiza et al. (2021, https://doi.org/10.1029/2020EF001508). In response to this article, we emphasize several distinctions between resilience and other systems concepts. These include distinctions between resilience, risk, and vulnerability, the tradeoff between resilience and efficiency, resilience contrasted with robustness, the relationship between resilience and sustainability, and finally methods for building resilience-by-design or resilience-by-intervention. Improving understanding of these concepts will enable planners to select resilience strategies that best support their system goals. We use examples from the 2020–2021 coronavirus pandemic to illustrate the concepts and the juxtapositions between them.

Preface

This work was conducted for the US Army Corps of Engineers (USACE); funded in parts by the US Army Corp of Engineers Military Funding Program FLEX on Resilience and Compounding Threats.

The work was performed by the US Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, the deputy director of ERDC-EL was Dr. Brandon J. Lafferty, and the director was Dr. Edmond J. Russo Jr.

This paper was originally published as S. Galaitsi, M. Kurth, and I. Linkov, "Resilience: Directions for an Uncertain Future Following the COVID-19 Pandemic," *GeoHealth* 5, no. 11 (November 2021): e2021GH000447, https://doi.org/10.1029/2021gh000447.

COL Christian Patterson was commander of ERDC, and Dr. Beth C. Fleming was the director.

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Resilience: Directions for an Uncertain Future Following the COVID-19 Pandemic

Plain Language Summary This commentary builds upon the discussion of resilience in Urquiza et al. (2021, https://doi.org/10.1029/2020EF001508). We discuss several distinctions related to resilience, both in urban contexts and the broader resilience literature. These include resilience versus risk and vulnerability, resilience versus efficiency, resilience versus robustness, and resilience versus sustainability. Finally, we contrast resilience-by-design with resilience-by 64 intervention. Understanding the differences between these concepts can help planners select strategies that best support their system goals. We use example from the 2020–2021 coronavirus pandemic to illustrate the concepts.

Though interest in applying the concept of resilience to recover from crises has been growing in the last two decades, the COVID-19 pandemic has further spurred its framing for complex systems (see Klasa et al., 2021). The paper by Urquiza et al. (2021) provides a thorough summary of the different analytical definitions and features of resilience, and contributes to existing resilience research, including the National Academy of Sciences (Cutter et al., 2013) report on disaster resilience, Connelly et al. (2017), Häring et al. (2017), Klasa et al. (2021), Larkin et al. (2015), and many others. Resilience is often presented as a system property that supports the recovery of critical functions following a disruption to that system. This commentary builds on the analysis of Urquiza et al. (2021) by juxtaposing resilience with other system properties that apply to both urban systems and broader resilience applications. The issues we discuss are useful to refine terminology in resilience explorations.

1. Resilience Versus Risk

Urquiza et al. (2021) aimed to clarify the relationships between resilience, risk and vulnerability, but we feel that more remains to be said on this point. Resilience, risk, and vulnerability can be defined in relationship to a system, and doing so enables better understanding the independent roles of risk and resilience. *Resilience* is a system property that can be built in engineering systems and results from evolution in natural systems (see the discussion in Section 4 about demarcating the bounds of a system). *Vulnerability* is also a system property; it helps us to understand how a system's characteristics can make the system weak in certain circumstances. Vulnerability has been defined many different ways in relationship to resilience (Bakkensen et al., 2017), but there is also precedent for considering vulnerability as a component of risk's Threat, Vulnerability, Consequence triplet. Thus, *risk* is a function of vulnerability, a system property, but also of external influences to that system, specifically threats that may or may not emerge over time or space. Risk is an integrated measure used to assess the likelihood of specific outcomes (e.g., failure of system or probability of death). Risk, hence, cannot be completely understood by examining the system alone, whereas resilience is predominantly a function of internal system properties. Furthermore, risk assessments often aim to prevent or defuse threats before they can cause damage or to decrease system vulnerability with protective infrastructure, while resilience focuses on enhancing system recovery and adaptation in the period after damage occurs and is independent of the threat that causes the damage (Linkov & Trump, 2019; Linkov et al., 2018). Systems with similar risk profiles may differ in their resilience depending on how system protection is designed and which threats the protection will prevent, neither of which correlate with resilience capabilities.

The coronavirus pandemic has demonstrated that threats and the risks associated with them are not always predictable in their emergence or their impacts. Lack of predictability in an increasingly complex world limits the value of risk assessments for low-probability high-consequence events. However, building system resilience can provide value by allowing faster recovery and adaptation after system disruptions, whether they were predicted or not. In imagining the impacts of an uncertain future threat, the concepts of vulnerability, risk, and resilience are all informative, but in the event of an actual disruptive event, resilience will be most influential in determining the system's future because resilience sets its trajectory for recovery. Framing the difference between resilience and risk is critical to system management because of the inherent tradeoffs in selecting management strategies for risk mitigation and resilience enhancement.

2. Resilience Versus Efficiency

In Urquiza et al. (2021) Section 3.3: Examining timeframes of resilience in terms of persistence versus evolution, the authors touch upon the idea of substitution within a system that enables maintaining a certain level of service. However, this is couched within a discussion that contrasts repurposing structures versus changing or adapting structures at certain thresholds. A discussion of trade-offs between resilience and efficiency is lacking, and the distinction is important because there are situations where they may be mutually exclusive (Trump et al., 2020).

Resilience may require redundancies or alternative ways to execute the same function. In the long-term, implementing such redundancies can be achieved via adaptation of system components that previously served other purposes. However, it is useful to examine methods for reliably achieving redundancies in the short-term through investments in resilience. Such redundancies represent a trade-off with the system's leanness and efficiency because redundancies equate to unused capacity or investment. During a disruption, this capacity may be crucial to avoiding costs and supporting system resilience (Kurth et al., 2020). In contrast, a system that prioritizes efficiency, for example, could include commercial enterprises that seek to reduce costs by trimming material or employee redundancies. Such systems, like the just-in-time manufacturing model, may be more vulnerable to disruptions if workers or specific materials become unavailable (Brakman et al., 2020).

Both these scenarios—of worker and material shortages—emerged during the coronavirus pandemic. During non-pandemic times, hospitals function efficiently in that they do not have stockpiles of personal protective equipment (PPE) nor unused labor capacity. COVID-19 patient surges in hospitals strained available staff, and depleted PPE stockpiles at a time when PPE was most needed and hardest to obtain, while halting hospitals' primary revenue source, elective surgeries (Taylor, 2020). These problems cascaded as nearly 3,000 U.S. healthcare workers died of coronavirus in 2020, with roughly one-third of those deaths estimated to involve inadequate provisions of PPE (Jewett et al., 2020). Additionally, in April 2020, the health care industry addressed revenue gaps in part by cutting 1.4 million healthcare jobs, including 135,000 hospital jobs (Fadel et al., 2020), reducing redundancies for the workers that remained. At a moment when medical workers faced growing workloads and dangerous and emotionally draining work, their access to PPE and time off diminished. Although many hospitals received government bailouts (Silver-Greenberg et al., 2020), the extent of resilience of the medical establishment during the pandemic was often determined by individuals who gave more of themselves to their jobs. Many heroes emerged, but there may be a long-term attrition of medical workers to due to all the pandemic impacts (Murphy, 2020). Systems can be more reliably resilient when they have built-in redundancies and do not require exceptional behavior from individuals; in general, patients at understaffed hospitals were less likely to survive (Rosenthal et al., 2020). Thus, when efficiency has precluded the types of redundancies that enable broad system resilience, stressing system components to enable short-term resilience can come with high costs including compromising the system's long-term ability to perform its critical functions.

In times of crisis, lean systems can fail catastrophically. Managers must understand that an efficient system comes at the cost of resilience. Improving resilience for systems like hospitals requires acknowledging that resilience and efficiency need to be treated differently. Future research can establish an optimal combination of resilience and efficiency measures to meet short-term system resilience needs.

3. Resilience Versus Robustness

The concepts of resilience and robustness have similar outcomes but arrive there via different processes. However, Urquiza et al. (2021) and many others equate them in some instances. Resilience is the ability to recover from a disruption, while a robust system is unaffected by the disruption (Galaitsi et al., 2021). In Urquiza et al.'s example about a household switching to wood or petrol-based energy to cope with erratic energy supply, this switch (or adaptation) does not make the household more resilient, it makes it more robust. A household that has switched energy sources is not obliged to rely on an inconsistent system; it has become robust because it is no longer affected by disruptions. A resilient household would continue to experience disruptions of electrical supply but have coping mechanisms, such as a backup energy supply. Both households are able to provide for their critical functions, but when the energy supply is disrupted, only the resilient household experiences those disruptions since the robust household has restructured itself to be unaffected.

The confusion of resilience and robustness is evident elsewhere in Urquiza et al. (2021) by a focus on "maintaining" service (Sections 3.1 and 3.3) rather than recovering service when discussing resilience. Resilience can only exist in the context of a disruption that has affected the system itself, including its ability to maintain service. A system that faces disruption without any consequences is robust, not resilient.

To again use an example from the coronavirus pandemic, jobs that were able to pivot to online formats, like telehealth or virtual schooling, were resilient to the disruptions of the pandemic. Jobs that had been remote before the pandemic, such as instructors for smart home gym equipment, were robust to the pandemic disruption.

Additionally, Urquiza et al. (2021) rely on definitions in Galaitsi et al. (2021) of adaptability, agility, robustness, and resistance to contrast ecological and engineering resilience. However, we contend that robustness does not belong in the set. According to Galaitsi et al. (2021), adaptability and agility characterize a system's reaction to being disrupted and thus may incorporate (or yield) resilience. Resistance implies some level of damage to system functionality that would require recovery and hence resilience. Galaitsi et al. (2021) argue that a robust system would not need to recover, so robustness is an alternative to resilience, not a form of it.

In planning, robustness and resilience are both desirable, though they would never be necessary simultaneously because complete robustness precludes resilience. However, of the two concepts, system resilience may be much easier to ensure over time since robustness may only be valid for a small subset of threat manifestations or for a limited magnitude of disruption. Thus, understanding the difference between the two concepts will be critical to assuring desirable system performance outcomes following threat emergences, both predictable and unpredictable.

4. Resilience Versus Sustainability

Resilience and sustainability are often equated, but they differ despite their ability to coordinate (Marchese et al., 2018). Though Urquiza et al. (2021) do not explicitly examine resilience's relationship to sustainability, interactions between these concepts arises in Urquiza et al. (2021) Section 3.4: Intentionality of Resilience: memory and learning versus self-transformation and governance. Urquiza et al. (2021) contrast two forms of resilience: that which arises as an undirected system response to a disruption, and resilience that is possible only with intentional, directed, and governance-mediated interventions. Both these systems are resilient, but here we use them as a lens through which to view system sustainability.

Galaitsi et al. (2021) theorized that a sustainable system is one that can operate without external support, both in the presence or absence of a disruption to those operations. A system that is automatically supported by internal elements, would be self-sustaining, whereas needing external support implies the system has become unsustainable within the new conditions. During the coronavirus pandemic, U.S. federal Payment Protection Program (PPP) loans provided needed additional funding to support the resilience of businesses, with the hope that businesses would be able to continue operating. Judging the sustainability of an entrepreneurial system partially depends on how the bounds of the system are imagined. If an American business exists in a system that encompasses the federal government and is presumed to automatically support faltering businesses, then this system is sustainable because it contains sufficient redundancies to enable businesses to recover and then maintain operations. The redundancy is the money accumulated by the federal government that, in a perfect sustainable system for businesses, would be directed towards supporting business. However, in reality many businesses did not access PPP loans during the coronavirus pandemic, or the PPP loans available were insufficient; this indicates that the business system bounds did not include the federal government's support, and thus a business model reliant on federal support may not have been sustainable during a pandemic. Where sustainability is defined as not needing external support, the boundaries that mark a support as internal or external matter in determining whether a given system is sustainable.

We note too that sustainability is distinct from reliability: a system may be unsustainable but can still be reliable as long as an external force continues to provide the necessary support. However, the fact that decision-making to provide the necessary support remains outside that system's control makes the entire arrangement somewhat precarious. As in the case of businesses that still closed despite availability of PPP loans, a sustainable system that can provide support internally has less that can go wrong in accessing that support.

The coronavirus pandemic disruptions have revealed the extent to which some industries are not operating resiliently or sustainably—one example is the struggling child care industry. This has produced a movement to “stabilize” child care. In order for the child care industry to be truly sustainable, structural changes are needed that make the industry resilient enough not only to disruptions, but to operate profitably and beneficially during normal times. This is currently not the case: high operating costs of child care typically make programs unprofitable for owners, and low-paying for staff, causing high staff turnover, which affects the quality of care provided. Structural changes to better fund child care programs are the target of many emerging 2021 bills, both state and federal (see Massachusetts' SD.1307 and HD.1960, Minnesota's HF1024, Washington's 5237 (Senate) and 1213 (House), and Federal HR.7201). While government bailouts support resilience, they are not necessarily sustainable because bailouts are always government-mediated, and thus situations or administrations could arise in which they are not forthcoming. To truly ensure sustainability for the child care industry, guaranteed subsidies, provided by law from state or federal budgets, will be necessary. Urquiza et al.’s lens for the intentionality of resilience is useful, but here we have emphasized the uncertainty around reliability for these supports, with implications for system sustainability.

5. How to Build Resilience?

The question of how to build resilience reflects Urquiza et al. (2021)'s analytical framing of intentionality, discussed in Section 3.4: Intentionality of resilience: memory and learning versus self-transformation and governance. In this section, Urquiza et al. (2021) consider the possibility that a system can be “steered or ‘governed’ towards a desirable outcome.” Here we expand upon this idea to consider how resilience might be built by design or by intervention (Linkov et al., 2021), or a combination of the two (Kott et al., 2021). Resilience-by-design builds the capacity for a system to recover critical functions after a disruption within the structure of the system. An example is the expansion of telehealth during the coronavirus pandemic, in which the structure of the cyber and healthcare systems could reformat and recover without external inputs or aid. Another strategy to create resilience-by-design is planned redundancies in contrast to highly efficient systems that minimize extra components, as described above. Resilience-by-design has not been properly implemented if the internal components providing the support become unduly stressed or break. Such is the case of individual heroics, like medical staff during coronavirus surges. In the case of heroics, the costs to the medical industry may play out over time as an attrition of burnt-out employees, which is not true resilience.

Resilience-by-intervention presumes that an external resource will be available, as needed, to support system resilience. The external resource may be an umbrella resource available to any number of systems under the right conditions, such as federal disaster aid in the United States. A system that is able to transfer the cost of resilience to another entity may be more agile, efficient, and risk tolerant in its normal operations. However, such offloading may only be advisable under certain circumstances when there is sufficient trust to assure that the resources will be made available as needed. For example, health insurance should provide patients with resilience-by-intervention. In the US, however, the insurance system allows for surprise medical bills, wherein patients with healthcare coverage may receive bills of hundreds or thousands of dollars that their insurance will not cover despite a lack of alternatives for needed services (KFF, 2021). As of December 2020, the US government has begun to take steps to address this failure in resilience-by-intervention.

In particular, the concepts of redundancy and sustainability raised in this commentary are, in some ways, parallel to resilience-by-design. Resilience-by-design will generally include redundancies, which conflict with attempts to design very lean, efficient systems. Sustainability implies that all the supports needed are already internal to the system, as in the system "design." However, leanness, the converse of redundancy, is also associated with sustainability, at least in the environmental sense, because it connotes less waste. But since leanness reduces resilience, it can also reduce sustainability in the long-term. These concepts have overlapping boundaries, and system management goals should balance their benefits with their drawbacks. In a complex system, resilience can be realized in a variety of ways that may complement or conflict with other system aims. Urquiza et al. (2021) significantly contributed to the literature by framing analytical distinctions of resilience including scope, timeframes, intentionality, scale, and urban applications; here we have provided some critique as well as expansion of these distinctions. Ultimately, planners have many tools to assure the highest level of system performance over time, and gaining a better understanding of the differences between resilience and other positive system attributes, such as sustainability, efficiency, and robustness, will help them identify the best strategies to protect or assure recovery for their critical system functions before disruptions occur.

Conflict of Interest

The views and opinions expressed in this paper are those of the individual authors and not those of the US Army or other sponsor organizations.

Data Availability Statement

Data were not used, nor created for this research.

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REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED START DATE	END DATE
April 2025	Journal Article		

4. TITLE AND SUBTITLE
Resilience: Directions for an Uncertain Future Following the COVID-19 Pandemic (Postprint)

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

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Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/EL MP-25-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A. Approved for public release: distribution is unlimited.

13. SUPPLEMENTARY NOTES
Funded in parts by the US Army Corp of Engineers Military Funding Program FLEX on Resilience and Compounding Threats. This paper was originally published as S. Galaitsi, M. Kurth, and I. Linkov, "Resilience: Directions for an Uncertain Future Following the COVID-19 Pandemic," *GeoHealth* 5, no. 11 (November 2021): e2021GH000447, https://doi.org/10.1029/2021gh000447.

14. ABSTRACT
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15. SUBJECT TERMS
COVID-19 Pandemic, 2020-, Organizational resilience, Risk assessment

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	C. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
Unclassified	Unclassified	Unclassified	SAR	13

19a. NAME OF RESPONSIBLE PERSON	19b. TELEPHONE NUMBER (include area code)