An Introduction to 2nd Volume of the Resource Guide on Resilience

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Society is increasingly reliant upon complex and interconnected systems to foster virtually all elements of modern life. From basic infrastructure to public health and medicine to business and finance, these systems are often predicated upon interdependencies in order to deliver better, faster, and less expensive services. Such interconnection has opened the door to incredible innovations in organizational and infrastructural operation yet has also left many critical and foundational societal systems at risk of systemic disruption.

A growing area of inquiry to best prepare the complex infrastructural, social, and environmental systems which sustain modern life is *resilience.* Across its many disciplinary and theoretical uses, resilience typically emphasizes the capacity of a system to 'bounce back' and adapt to changes within its environment. As both a philosophical topic and a methodological practice, resilience has exploded in usage over the past several years. Its effect upon policy is tangible, including efforts within the United States, European Union, OECD, United Nations, People's Republic of China, and countless other nations and governing bodies (Larkin et al., 2015; Corfee-Morlot et al., 2012; Linkov, Trump & Keisler, 2018). The diversity of resilience applications is equally manifest, from infrastructural and engineering resilience to complex adaptive ecosystems, economic and financial markets, and psychosocial behavior at varying levels of abstraction (Linkov & Trump, 2019).

This level of growth presents a key challenge – how might we arrive at shared core concepts of resilience without unduly restricting valuable research into a scientific discipline or policymaking practice? This is a subtle question which reflects upon the need for a common language by which resilience can be communicated and implemented across disciplines and borders, yet equally work within the political, institutional, scientific, and cultural contexts which comprise a given project, venture, or activity (Alexander, 2013).

In late 2016, the 1st Volume of the Resource Guide on Resilience was assembled to address this concern. Across dozens of submissions, participants unpacked multiple definitions, analytical methods, tools, and governing strategies by which resilience is formulated and implemented (Linkov, Trump & Fox-Lent, 2016). With such a diversity of knowledge on the foundational principles of resilience, the 1st Volume of the Resource Guide serves as a core open-source document where interested parties can understand what resilience is, as well as identify the shared principles and opinions behind the analysis and implementation of resilience on a global scale.

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Papers presented in the 1st volume were tasked to accomplish the following:

1) Clarify how resilience differs and complements existing practices with risk assessment, and
2) Define *resilience* as a systems-focused approach which emphasizes the capacity of that system to recover from and adapt in the aftermath of disruption.

The first point is a concern of governance and semantics. Risk assessment has evolved as the go-to exercise to explore how a specific hazard or threat might exploit a vulnerability within a given system and what the consequences of that hazard or threat might be. Individual disciplines, government agencies, and private sector stakeholders each possess their own approach to executing such risk assessment in a manner that is consistent with statutory requirements as well as social and institutional norms (Jasanoff, 2011). These processes work well within an environment of clearly defined hazards and threats to thoroughly understood risk receptors. However, such risk assessment becomes less capable of characterizing and prioritizing threats, clarifying system vulnerabilities, or reasonably assessing threat consequences within an environment of high complexity and interconnectivity within and between systems – there simply is not enough data to populate a risk assessment, nor is there sufficient expertise to confidently identify *all* of the threats which might exploit system vulnerabilities and generate cascading impacts to the system and its dependencies (Holling, 1986; Trump et al., 2017).

Resilience thinking and assessment is a likely candidate to complement existing risk assessment practices within such environments of high uncertainty or system complexity (Gunderson, 2001). Rather than focusing upon any single threat (or requiring that all threats be identified and characterized to inform a system's risks), resilience instead requires analysts to unpack the characteristics that define a system's activities and baseline state of performance – including any external dependencies or internal sub-systems (Palma-Oliveira & Trump, 2016). This approach allows analysts to understand how a system performs when one or more of its critical functions are degraded, destroyed, or otherwise rendered inert. To best protect complex systems from lasting and widespread failure and loss of service, various strategies are needed to improve the system's capacity to absorb and recover from risk – thereby limiting losses as much as possible.

The second point is a concern of framing and analytics. We argue that risk assessment is primarily focused on preparing a system to *withstand and absorb* threats of a specific nature or intensity. Examples of such an approach are numerous, from coastal flood preparedness to bridge usage and maintenance scheduling to aircraft inspections and safety assessment. On the other hand, we argue that the novelty behind resilience is a need to emphasize the capacity of a normatively positive system to *recover and adapt*, following the occurrence of adverse events (Linkov, Trump & Keisler, 2018). This distinction might appear minor but represents a significant departure from how current assessment is conducted.

One key distinction includes the general need for a resilience-based approach to consider low-probability, high-consequence events. A risk-based approach often struggles to inform decisions of this nature, where an analyst either places too much emphasis or too few resources onto the given risk receptor's ability to withstand and absorb the shock of an adverse event. For resource-constrained agencies and organizations, such events are often prohibitively expensive to fully defend against. A recurring example includes preparedness for severe coastal storms – preparing every mile of coastline for a Category 5 Hurricane would be ruinously expensive and politically indefensible. Likewise, a resilience-based approach would instead offer an improved understanding of which essential components of a system would contribute to the greatest loss of function if taken offline. After identifying these critical functions, an analyst may then develop countermeasures or redundancies to improve the capacity of these functions to withstand and recover from their initial disruption.

A key theme here is the notion of *systemic threats*. Such threats are characterized by their capacity to percolate across complex interconnected systems – either through an abrupt shock, or gradual stress (IRGC, 2018). Systemic threats are particularly difficult to model and calculate via a risk-based approach due to a mixture of the weak signals, which herald a potential upcoming systemic risk event, as well as the nested interaction effects by which a systemic threat incurs disruption to a system in an indirect manner. For example, the Financial Crisis of the previous decade began as a collection of relatively contained failures of financial firms, which ended in a substantial financial collapse across much of the world. In a separate yet related volume to the Resource Guide on Resilience, the International Risk Governance Center's Guidelines for the Governance of Systemic Risks unpacks steps to identify, manage, and govern such systemic threats from the perspectives of policymakers and industry stakeholders alike. Resilience is an often-essential component for the governance of systemic risks, where such a governing approach emphasizes the need to limit the potential for cascading disruption as well as to build redundancies and countermeasures to quickly recover from and adapt to such systemic threats in an expeditious manner.

When data is in abundance or relatively easy to acquire, or system complexity is limited and system threats are well characterized, risk-based approaches of assessment are the gold standard for most regulatory agencies or industry stakeholders to follow. However, when one or more of these characteristics become more uncertain or complex, resilience-based approaches may help complement any deficiencies that a risk-based approach presents. Such resilience-based concepts have been discussed and applied in many situations and disciplines globally and are growing in prevalence and scholarly attention. The opinions of the authors within this Resource Guide reflect the diversity of such approaches and perspectives, and collectively ask and answer important questions related to the further development and implementation of resilience in various industries and projects.

Presenting the Second Resource Guide on Resilience

This 2nd Volume of the Resource Guide on Resilience delves further into the more specific domain-based views on resilience, as well as critical questions in the field which remain underrepresented in scholarly literature and policy documents. For starters, the 2nd Volume reviews expertise from multiple domains, including environment and ecology, business, economics, and finance, and infrastructure and engineering. Each author presents an understanding of resilience as it is conceived and applied within their domain, as well as how resilience compares with more traditional statutory requirements of risk assessment, and how risk and resilience are complementary concepts. Many authors emphasize the dynamic property and process that comes with resilience, illustrated by Woods' (2018) submission aptly titled "Resilience is a Verb."

After defining resilience within their field and articulating differences between risk-based and resilience-based approaches, authors were asked to comment upon two important questions regarding the framing and consequences of a resilience-based approach. One question centers upon potential downsides that a resilience-based strategy might evoke – either through implicitly changing the characteristics or properties of systems and making them more susceptible to losses or collapse, or altering the frames or perceptions of individuals relying upon these systems to behave in a different or more risk-seeking manner. A second question includes the author's view of the role of resilience to enable or foster the capacity of systems to adapt or transform in the face of important changes that can trigger shocks and disruption.

The potential downsides of resilience are often undiscussed in scholarly literature as well as within many important policy discussions. Indeed, resilience is often framed as being a universally positive trait, with little reflection upon how a recovery and adaptation-based approach can fundamentally change the way a system and its stakeholders function and behave (Nelson et al., 2007; Palma-Oliveira & Trump, 2016). Many authors within this Resource Guide reflect upon their concerns of a 'downside' of resilience as arising from (a) increasing brittleness in some components of a system in order to strive for robust recovery in others, or (b) a fear that a resilience-based approach might induce some concern of moral hazard, or excessive confidence in the capacity of a resilient system to quickly recover from any and all disruptions, and therefore contribute to increasing a risk appetite or exposure.

Our authors described multiple potential drawbacks or concerns associated with developing resilience in various domain-specific approaches. Baum (2018) introduces the potential concern of moral hazard. Likewise, Aldrich et al. (2018) express concern at the tradeoffs inherent to developing resilience in societal contexts – in other words, they argue that decision-makers routinely prioritize spending on physical infrastructure over social system resilience, which can further entrench and enflame public tensions and social deficiencies. Stojadinovic (2018) further argues that resilience-based development in civil infrastructure may become unpopular due to its relative cost versus the uncertain likelihood that a disruption to such infrastructure will occur in the first place. Likewise, from an ecosystems perspective, Levin (2018) argues that furthering resilience-based approaches may extend the lifespan of suboptimal or undesirable system components, rather than enabling the system to transition to a more preferred state.

Similar to the consideration of potential downsides of pursuing resilience-based strategies, transitions are equally a critical yet often under-discussed component of system resilience. Complex adaptive systems are constantly in flux and incorporate new information and capabilities to best respond to emerging trends and stresses within their surrounding environment (Hirota et al., 2011; Comfort et al., 2001). Acknowledging the broad diversity of systems which transitions apply to, we have asked experts in areas within each of the three domains listed above to discuss how adaptation and transitions apply to their area of research. In their pieces, several authors describe how resilience enables adaptation and transformation, either before important transitions or to cope with the consequences of important undergoing transitions. Finally, several authors discuss how resilience assessment can also evaluate the capacity of a system to adapt and transform to avoid dangerous disruptions.

Authors of this Resource Guide, volume 2, individually explore the role of resilience to enable and foster system transitions. From an environmental and ecological perspective, Allen (2018) and Palma-Oliveira & Trump (2018) respectively discuss how ecological systems are defined by a constant influx of environmental change, where systems (e.g., a lake), sub-systems (e.g., the pH level of the lake), and supra-systems (e.g., the regional drainage of water into the lake) each shift to accommodate new and recurring environmental stressors. Allen discusses the constant and multi-scalar environmental change as *panarchy*, while Palma-Oliveira & Trump reflect upon the ecosystem transition concept known as *basins of attraction*. Within both pieces, the authors respectively argue that ecological transitions reflect moments where an existing environmental state can realign into a similar state or transition into one that is entirely different from the biodiversity and ecosystem health currently available. A critical takeaway point from these and other authors is that such transitions or the crossing or certain thresholds can drive a system towards a normatively positive or harmful ecosystem structure.

Similar themes were raised by other authors in this regard. For social and organizational resilience, Pulakos & Lusk (2018) as well as Kudesia & Reb (2018) respectively describe the preconditions of social interaction and trust which are needed to transition an organization, business, or government away from a socially undesirable or unsustainable state, and towards one that is preferable. From the perspective of infrastructural resilience, Furuta & Kanno (2018) as well as Kott (2018) reflect upon the need to account for nested interdependencies of engineered systems, where transitions and adaptive capacity percolates from sub-systems into broader infrastructural systems such as with the experience of the Great East Japan Earthquake and the subsequent disaster at the Fukushima-Daiichi Nuclear Power Plant in 2011, or military systems and cybersecurity.

Resilience is definitely a topic of growing interest not just as a philosophical or scholarly exercise, but increasingly as an aspirational goal for many complex systems facing systemic threats, and an appealing pragmatic approach to governing risks with a low probability of occurrence and potentially a high level of negative consequences, shocks, disruptions and cascading failures. This compendium of knowledge expands upon the 1st Volume of the Resource Guide on Resilience by providing a more in-depth view of disciplinary applications of resilience, as well as key questions regarding the implications of resilience-based strategies moving forward.

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