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PERSPECTIVE

Navigating the precipice: Lessons on collapse from the Late Bronze Age

S. E. Galaitsi[1] | Benjamin D. Trump[2] | Eric H. Cline[3] | Maksim Kitsak[4] | Igor Linkov[2]

[1]Credere Associates LLC, Westbrook, Maine, USA

[2]Engineer Research and Development Center, US Army Corps of Engineers, Vicksburg, Mississippi, USA

[3]Department of Classical & Near Eastern Languages & Civilizations, George Washington University, Washington, District of Columbia, USA

[4]Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Delft, CD, Netherlands

Correspondence
Benjamin D. Trump, US Army Corps of Engineers, Vicksburg, Mississippi, USA.
Email: Benjamin.d.trump@usace.army.mil

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Abstract
Around 1200 BCE, the societies of the Late Bronze Age (LBA) in the Eastern Mediterranean experienced a collective collapse, evident in the archeological remains of destroyed and abandoned cities. Following our prior explorations in this topic, we hypothesize that the network structure between the LBA societies amplified compounding threats, producing a cascade of failures that culminated in a precipitous broad systemic collapse. The network, so often seen as a conduit for prosperity, propagated the problems of individual nodes. Herein we discuss the findings of Linkov et al.'s (2024) network analysis of the LBA collapse and its implications regarding vulnerabilities in our current global context as our systems surpass carrying capacity in our pursuit of societal complexity.

KEYWORDS
collapse, Late Bronze Age, network analysis

1 | INTRODUCTION

The historical record of the Late Bronze Age (LBA) in the Eastern Mediterranean reveals extensive interconnections between societies that fostered advancements in cultural, economic, and political domains. These ties supported societal development despite periodic disturbances throughout the Bronze Age. However, around 1200 BCE, the archeological record indicates a sudden and widespread collapse of Bronze Age societies. This collapse has sparked extensive debate among archeologists regarding its origins and propagation mechanisms.

This perspective examines the LBA collapse not merely as a distant archeological curiosity but as a valuable case study in systemic risks with direct applications for today's globalized systems. By applying network analysis to the archeological record, we gain insights into the structural vulnerabilities that may have contributed to this historical collapse, and, by extension, we can identify potential weaknesses in our current global context. Linkov et al. (2024) constructed a network model based on the LBA archeological record to analyze the collapse sequence. Their simulation demonstrates a historically plausible collapse trajectory for LBA societies, revealing structural vulnerabilities within the network. These findings suggest that latent vulnerabilities may already exist in our modern global systems as we approach or exceed environmental carrying capacities in our pursuit of societal complexity.

The LBA collapse offers a unique opportunity to study the interplay between network structure, environmental pressures, and societal stability. As we face multiple global crises today, including climate change, resource depletion, and geopolitical tensions, the lessons drawn from this historical example become increasingly relevant. By understanding the mechanisms that led to the LBA collapse, risk analysts can develop more sophisticated models and strategies to anticipate and mitigate potential systemic failures in our current global networks.

This perspective seeks to bridge the gap between archeological insights and modern risk analysis methodologies, demonstrating how historical case studies can inform our understanding of complex system dynamics and guide the development of more robust and resilient societal structures in the face of emerging global challenges.

2 | COMPLEX SYSTEMS AND THE LATE BRONZE AGE

The LBA in the Eastern Mediterranean comprised a complex network of interconnected societies, including the Canaanites, Egyptians, Mycenaeans, Hittites, and Babylonians. This intricate web of relationships fostered unprecedented prosperity and cultural exchange but also set the stage for a dramatic collective collapse (Cline, 2021; Linkov et al., 2024).

The economic foundation of the LBA network rested on extensive trade routes that linked distant empires and city-states. Archeological evidence, such as the Uluburun shipwreck, reveals the sophistication of these trade relationships that shipped copper, tin, raw glass, grain, fruit, spices, and perfume ingredients from at least seven distinct polities (Cline, 2021). Replications of art forms, especially fresco paintings, attest to the flow of ideas and cultural practices (Cline, 2021). However, the prosperity that emerged was not just built on trade; it was also bolstered by agricultural yields to feed the growing urban populations and support the artisan and warrior classes pivotal to LBA society. Agriculture had matured to a commodity that could be traded; insufficient harvests could be supplemented through trade network connections, allowing populations to grow beyond the constraints of local resources.

The political landscape of the LBA was equally intricate, characterized by a web of diplomatic alliances and rivalries. The Amarna letters provide insight into the sophisticated diplomatic correspondence of the time, such as between New Kingdom Egypt and its neighbors. Linkov et al. (2024) suggest that these political ties were fundamental to societal stability, creating a system where the collapse of one polity could trigger a cascade of instability across the network. For example, the relationship between the Hittites and Egyptians, culminating in the Treaty of Kadesh, exemplified how diplomatic relations could attest to periods of diplomatic peace and economic exchange. Conversely, the breakdown of these alliances at times disrupted trade, precipitated military conflicts, and created economic turmoil (Friedman, 2016; Kristiansen & Suchowska-Ducke, 2015; Weiss, 1982).

Environmental factors added another layer of complexity to this system. Paleoclimatic data indicate significant climatic shifts during the LBA, including prolonged periods of drought (Kaniewski et al., 2020; Langgut et al., 2015; Weiberg & Finné, 2018). These environmental changes directly impacted agricultural productivity, straining the economic and political systems that relied on consistent food supplies. The agricultural systems, once the backbone of contemporary palace economies and international trade alike, became unable to sustain the growing populations of their urban centers.

The collapse of this intricate system began in the early 12th century BCE, manifesting in various forms across different sites. Some cities, like Ugarit, show evidence of enemy attacks, whereas others, such as Ras Bassit and Hattusa, were abandoned and later destroyed. The destruction patterns in cities like Hazor and Lachish suggest internal conflicts, whereas others, including Ekron, Ashdod, and Tell Kazel, were destroyed and subsequently reinhabited by new populations (Cline, 2021). Tell Tweini (ancient Gibala) experienced severe destruction and was subsequently abandoned. On mainland Greece, some prominent Mycenaean cities were destroyed, whereas others were abandoned (Cline, 2021). At Hazor in Canaan, only the elite sections of the city burned, whereas at Lachish, the destruction may have only been limited to the temple area, both possibly suggesting internal instigators of the destruction. The details of each of these stories can be found in Cline (2021).

The aftermath of the collapse was marked by a significant reduction in regional trade, literacy, and urbanization. Political entities contracted or fragmented, exemplified by the shrinking of the Hittite Empire. In Greece, connections with the Eastern Mediterranean diminished dramatically, whereas Mycenaean society devolved into isolated village economies (Davis, 2010). The sophisticated palace-centered administrative systems disappeared along with their associated writing systems and political institutions (Maran, 2009). Following the destruction of the Mycenaean urban centers, there were no new palaces built, and the concept of a supreme ruler, known as the wanax, disappeared from the contemporary political institutions (Maran, 2009). Elsewhere, once-vibrant palace centers were abandoned in favor of rural economies with significantly less reliance upon complex international trade for essential commodities. The trade system that brought tin from the Badakhshan region of modern Afghanistan or bananas and spices from South Asia shifted from centrally organized trade in the LBA to small-scale trade entrepreneurship (Scott et al., 2021). Where empires remained, such as Egypt, they contracted in area (Cline, 2021). Even the societies able to avoid destructive urban events saw their power diminish. In Egypt, the loss of trade partners and tributaries in the Levant compounded the financial and agricultural toll of warfare and contributed to a substantial loss in societal complexity and imperial governance.

3 | COLLAPSE, COMPLEXITY, AND CARRYING CAPACITY

The LBA collapse can be understood through two theoretical frameworks that illuminate the dynamics of complex political systems. Ken Arrow's concept of carrying capacity and Joseph Tainter's theory of collapse provide complementary perspectives on the vulnerabilities that led to the downfall of these advanced societies.

Arrow's discourse on carrying capacity emphasizes the intricate relationship between environmental resources and societal demands, economic systems, and institutions (Arrow et al., 1995; Arrow, 1974). This framework helps elucidate how LBA societies exceeded their ecological thresholds, setting the stage for collapse. As climate fluctuations intensified during the LBA (Kaniewski et al., 2019), agricultural yields declined, triggering a cascade of effects: reduced prosperity for palace economies, overburdened militaries, and food insecurity (Drake, 2012; Wilkinson, 1997). These environmental pressures were felt across the network, imposing new constraints on growth and sustenance while simultaneously reducing carrying capacity through diminished agricultural output (Kaniewski et al., 2019).

Complementing Arrow's perspective, Tainter's (1988) theory of collapse links increasing societal complexity to diminishing returns on investments required to maintain that complexity. This viewpoint illuminates the unsustainability of complex societal systems when confronted with mounting pressures. LBA societies had invested heavily in elaborate socio-political structures, extensive trade networks, and formidable military capabilities. Initially, these investments yielded substantial returns in economic prosperity and political dominance. However, as these systems grew more intricate, the marginal benefits of further investments began to wane, impacting local, ethno-imperial, and regional carrying capacities and trade networks.

Despite efforts to adapt, such as developing dry farming techniques in Southern Canaan and Egypt (Finkelstein et al., 2017; Kaniewski et al., 2013), the costs of maintaining such complexity in the face of environmental and economic challenges began to outweigh the benefits. This was particularly evident as societal carrying capacities became overstretched (Knapp & Manning, 2016; Weiss, 1982; Wilkinson, 1997).

The intersection of overstretched carrying capacity and diminishing returns created vulnerabilities within each LBA society. The interconnected nature of these societies then served to propagate and amplify these vulnerabilities across the network. Linkov et al. (2024) posit that the dissolution of these links, which had previously sustained and supplemented population needs, compounded local problems in connected nodes. This network effect could potentially trigger a system-wide collapse initiated by the disruption of as few as two nodes. Parallels can be drawn between the LBA scenario and our contemporary global situation; modern societies are pushing against the limits of global carrying capacity, evident in the overexploitation of nonrenewable resources, environmental degradation, and climate change. Simultaneously, the increasing complexity of our socio-political and economic systems demands ever-greater resources for maintenance, echoing Tainter's theory of diminishing returns.

From a risk analysis perspective, the fate of the LBA underscores the critical importance of balancing societal growth and complexity with sustainable resource use. The collapse of these advanced civilizations serves as a stark reminder that the pursuit of complexity, particularly under constrained environmental conditions, can lead to diminishing returns and potentially catastrophic societal collapse.

4 | PREVENTING COLLAPSE IN THE MODERN AGE: THE NEED FOR DATA ANALYTICS, RISK, AND RESILIENCE

The LBA collapse offers valuable insights into societal complexity and collapse, particularly when viewed through the lens of contemporary risk analysis. Arrow and Tainter's respective theories of carrying capacity and complexity and diminishing returns provide a foundation for understanding how advanced societies can become vulnerable to collapse. Modern advancements in data analytics and risk-informed innovation now offer unprecedented capabilities to identify, anticipate, and mitigate similar risks in our complex global societies, particularly given the emergence of risks ranging from resource management to climate risk to international conflict and various other trends and stressors.

Risk analysis provides a powerful framework for understanding and evaluating complex systems, offering insights that traditional systemic evaluations often overlook. By incorporating probabilistic thinking, scenario analysis, and quantitative modeling, risk analysis captures the nuanced interactions and potential cascading effects within intricate networks of social, economic, and environmental factors. This approach is particularly valuable in our increasingly interconnected world, where local disturbances can rapidly propagate to create global impacts, much like the network effects observed in the LBA collapse. Risk analysis methods can account for the non-linear dynamics and emergent properties characteristic of complex systems, allowing for a more comprehensive assessment of potential vulnerabilities and resilience factors.

Network analysis, exemplified by the Linkov et al. (2024) LBA study, has emerged as a crucial tool in modern risk analysis for complex systems. This approach maps the intricate web of interdependencies within and between societies, revealing latent vulnerabilities and potential failure points. For instance, network analysis can predict how disruptions in global supply chains might propagate through interconnected networks, assisting decision-makers in building more robust and resilient systems. This type of analysis could have been invaluable in understanding and potentially preventing the cascading failures observed in the LBA collapse.

Advanced simulations, powered by significant computational resources, enable high-precision modeling of complex systems. These simulations are vital for exploring "what-if" scenarios, examining system responses to various stressors, such as environmental catastrophes, economic crises, or geopolitical unrest. By identifying critical tipping points, these simulations aid in preempting systemic instabilities and devising strategies to enhance system robustness. Such tools could help modern societies navigate the delicate balance between increasing complexity and tipping points to maintain sustainability. Risk-informed innovation represents a critical addition to this analytical toolkit. This approach recognizes that technological and process innovations can effectively expand or alter a system's perceived carrying capacity limits, directly addressing Arrow's concerns. Integrating risk analysis with innovative problem-solving can support developing adaptive strategies that not only respond to current challenges but also proactively reshape their trajectory. This approach is particularly relevant in addressing environmental and resource-based constraints, where innovative technologies and practices can lead to more sustainable and efficient resource use, thus extending carrying capacity described by Arrow and potentially averting the diminishing returns of complexity highlighted by Tainter.

Predictive modeling, leveraging historical data (see DeWitte et al., 2017, Linkov et al., 2014) and current trends, stands at the forefront of these advancements. The study of past civilizations, such as those of the LBA, can inform the development of our analytical tools for present and future challenges, such as identifying critical variables and relationships that might otherwise be overlooked in our models. Modern societies can leverage historical knowledge alongside cutting-edge technology to potentially avoid similar collapses. By applying sophisticated risk analysis methodologies, we can work toward building more resilient and sustainable societies capable of navigating the complex challenges of our interconnected world. The lessons from the LBA collapse serve as a stark reminder of the potential consequences of exceeding carrying capacities and the pitfalls of unchecked complexity. However, they also provide invaluable insights that, when combined with modern risk analysis techniques, can guide us in creating more robust and adaptable global systems, potentially averting the types of cascading failures that led to the downfall of these ancient civilizations.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest. The views expressed are of the authors alone, and not necessarily their host institutions.

ORCID

Igor Linkov https://orcid.org/0000-0002-0823-8107

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