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Updating Mental Models of Risk

Disasters are no longer isolated events. This demands a fundamental change in how we think about and respond to complex risk.

Relentlessly, the Santa Ana wind howls across the bone-dry hills of Los Angeles County. It's January 2025, just weeks after Christmas. Southern California's fire season used to last from mid-May to October, but over the past decade, wildfire has become a year-round threat. What were formerly historic infernos now break out every few years—2018, 2020. And now this. As the minutes tick away, residents frantically pack heirlooms and scoop up their pets. Flames leap across highways and engulf entire neighborhoods. The emergency alerts blare from smartphones, TV screens, and radios: *Leave now*. *Do not wait*.

Rewind to a few months earlier: late September 2024. Hurricane Helene is battering Appalachian communities with a ferocity few locals believed possible. Hurricanes are perceived as a coastal problem, yet deep inland, in Asheville, North Carolina, floodwaters are tearing through streets, swallowing cars, and ripping homes from their foundations. The French Broad and Swannanoa Rivers, swollen beyond recognition, devour entire neighborhoods. Mudslides roar like freight trains, burying roads and cutting off rescue routes. Residents are stranded on rooftops or swept away in the current. Asheville's water system collapses, leaving thousands scrounging for clean drinking water for weeks.

These events exemplify an emerging complex risk landscape in which cascading failures and compounding hazards create threats that exceed the sum of their individual parts. More than two hundred people lost their lives in Hurricane Helene, and damages totaled more than $100 billion. Even as federal emergency managers were picking up the pieces in Asheville and its environs, Los Angeles was on fire, further straining already depleted federal disaster-response resources. With estimated losses exceeding $200 billion, the Palisades and Eaton fires that burned greater Los Angeles constitute the costliest disaster in US history—so far.

The California wildfires and Appalachia flooding are on opposite edges of the continent, but they both expose the same underlying global crisis. As Earth's system dynamics shift, hazards are not just intensifying but also converging. The impacts of these events have grown while the time between shocks has shortened, leading to cascading risk: A pandemic weakens a community's capacity to handle a flood, a flood weakens the government's capacity to respond to a wildfire.

Importantly, risks are intensifying not only because there are more and fiercer disasters happening in quick succession, but also because human populations are increasingly susceptible and exposed to the associated hazards. This is no less true in wealthy countries such as the United States than it is in poor ones. Wealth is often thought of as a source of protection—a form of risk mitigation. Yet the security that money buys can paradoxically amplify certain risks. Insurance, for example, insulates a homeowner against financial ruin, but may inadvertently encourage building in risky spots like a floodplain or dry hillside.

And to some extent, wealth enables a deeply intertwined set of systems that are reliant on "things working," so a single hazard can set off a chain reaction of vulnerabilities. When a fire or hurricane damages power generators or forces them offline, water-treatment and communications systems fail, undermining disaster response, rendering digitally operated infrastructure more vulnerable to cyberattacks, and increasing the risk of illness and death. In these tightly linked cascades, disasters jump categories. A fire, for instance, can damage power infrastructure, crippling water treatment plants and leading to a lack of potable water. Similarly, widespread economic immiseration can erode public trust and fuel social discontent, escalating into political strife. These are not merely sequential events but intricate feedback loops where systemic failures in one domain exacerbate adverse outcomes in another, creating reinforcing cycles of disruption.

The emergent reality of complex risk demands a fundamental change in how we conceptualize it. To date, policymakers, risk managers, and insurers—to say nothing of ordinary people—have consistently treated disasters as isolated events. Our mental model imagines a linear progression of unfortunate, unpredictable episodes, unfolding without relation to one another or to their own long-term and widely distributed effects. A hurricane makes landfall, we rebuild, we move on. A pandemic emerges, we develop vaccines, we return to normal.

This outdated model of risk leads to reactive, short-sighted policies rather than proactive prevention and preparedness strategies. Key public programs are designed around discrete, historically bounded events, not today's cascading and compounding crises. For instance, under the US Stafford Act, the Federal Emergency Management Agency (FEMA) must issue separate declarations for each major disaster, delaying aid and fragmenting coordination when multiple hazards strike. The National Flood Insurance Program still relies on historical floodplain maps that by definition underestimate future risks from climate change. Federal crop insurance supports farmers against crop losses from drought, excess moisture, damaging freezes, hail, wind, and disease, but today diverse stressors such as extreme heat and pollinator loss are converging with other known risks.

Our struggle to grasp complex risk has roots in human psychology. The well-documented tendency of humans is to notice and focus on immediate, visible dangers rather than long-term or abstract ones. Even when we can recognize such longer-term and larger-scale threats, we typically put them aside to focus on more immediate and tangible short-term threats. As a result, lawmakers and emergency managers, like people in general, often succumb to what psychologists and cognitive scientists call the *availability heuristic*: Policies are designed to react to whatever is most salient, which tends to be the most recent, most dramatic incidents—those most readily available to the mind.

These habits—and the policies that reflect them—do not account for the slow onset of risks, or their intersection with other sources of hazard, during the time when disaster might be prevented. Additionally, both cognitive biases and financial incentives may lead people to discount future risks, even when their probability and likely impact are well understood, and to struggle with conceptualizing phenomena that operate on global scales. Our mental processes are good at understanding immediate, tangible risk, not complex risk scenarios evolving over time and space.

By recognizing these biases, decisionmakers can begin to develop risk frameworks that take them into account. In particular, policymakers, insurance companies, and emergency managers can choose to plan for modern risk, even if the human instinct is to be distracted by "isolated" incidents. That way, before the non-isolated incident occurs, communities will have resources to turn to—resources that focus attention on what needs to be done to mitigate risk before it arises.

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Of course, having a more accurate model of risk is only the first step; we also need the institutional capacity to act on it. In the United States, that capacity is now increasingly fragile at the federal level. Efforts are underway to convert FEMA into a block grant program, shifting responsibility to states without guaranteeing adequate funding, coordination, or oversight. This proposed decentralization risks creating highly uneven levels of preparedness and undermining national coordination during multistate disasters, leaving communities in less-resourced states disproportionately affected.

It is also unclear how key agencies that produce scientific assessments, such as the National Oceanic and Atmospheric Association, the Environmental Protection Agency, and the US Global Change Research Program, will be able to continue their vital work. Deep cuts to these agencies reduce the nation's capacity for identifying and understanding emerging, complex risks. Such reductions lead directly to diminished data collection, impaired research, and severely hampered

dissemination of critical information, forcing policy decisions to be reactive rather than proactive and evidence-based.

Even as the need for integrated, future-oriented resilience systems becomes clearer, the United States is moving in the opposite direction. Recent policy shifts move the burden of foresight and preparedness onto states, cities, tribal governments, and counties. In these jurisdictions, trust in public institutions may still be largely intact, and decisive adaptive leadership is still possible. Still, local communities often lack the resources and infrastructure to meet these challenges effectively. Even if this shift to local responsibility achieves critical success, it will be limited until affected communities mobilize to demand the kind of comprehensive, federally funded response that matches the scale of the threat.

So, in this emerging scenario of complex risk, what might a modernized framework look like? We propose an extension of the model developed in the Intergovernmental Panel on Climate Change's Sixth Assessment Report. In this model, risk emerges from four interlocking components: *hazard* (the immediate source of harm), *vulnerability* (the susceptibility of populations and systems to damage), *exposure* (the presence of people, assets, or systems in harm's way), and *response* (the capacity to anticipate, absorb, and adapt to hazards).

Although local and regional risk managers are well positioned to apply this framework within their specific contexts, the need to update a general understanding of risk extends far beyond any single jurisdiction. Individuals, communities, businesses, and institutions at every level must rethink how these components interact in an era of complex risk. Each component—hazard, vulnerability, exposure, and response—requires fundamental reconceptualization.

Hazard: beyond extreme weather

When we think of Earth-system hazards, we often picture headline-grabbing events such as heatwaves, hurricanes, floods, and wildfires. Media coverage reinforces the narrow view that discrete incidents like these constitute the entirety of risk. Yet the destructive potential of each event is intensified by overlapping sources of hazard—some enhanced by climate change—that are seldom recognized as amplifying risk.

For example, land-use decisions can magnify or mitigate risk. In North Carolina, deforestation and real estate development worsened the effects of Helene's extreme rainfall by destabilizing soil and increasing runoff. And intensive development in some dry regions of California, coupled with an aged electrical grid, have created conditions ripe for wildfire—conditions that have been amplified by prolonged drought and vegetation changes driven by rising temperatures.

Furthermore, by focusing on acute disasters, existing risk models poorly account for the many slow-moving, non-weather-related hazards fueled by rising temperatures. For example, increasing heat is altering the geographic range and seasonality of disease vectors such as mosquitoes and ticks, and accelerating the spread of malaria, dengue, Lyme disease, fungal pathogens, and other biological threats. Warmer conditions are likely to speed up bacterial adaptation to antibiotics, which is already a grave global health crisis. And as humans and animals migrate, we are brought into closer contact, raising the likelihood of new pathogen transmission and spillovers between species. Even invasive species, which are often characterized as a nuisance or an eyesore, can be a significant amplifier of disaster impacts. The Los Angeles fires were fueled by invasive eucalyptus and other oily, resinous nonnative plants that burn hotter than native vegetation. Similarly, the 2023 wildfires in Maui were powered by highly combustible invasive grasses from Africa.

Understanding and accounting for hazards in this new context will require a lens that can account for those that defy expectations because they are slow moving, disconnected, or seemingly trivial. One tool for conceptualizing this tangled emerging network of risk can be found in what have been described as the *nine planetary boundaries*—including biodiversity loss, pollution, nitrogen and phosphorus flows, land system change, and freshwater use—many of which are crossing critical thresholds.

Vulnerability: misjudging the causes of risk susceptibility

In the context of risk, vulnerability refers to the susceptibility of populations, systems, or assets to the impacts of hazards. For example, a community's vulnerability is often discussed in terms of its physical infrastructure or socioeconomic status. However, many other factors also influence the community's vulnerability, such as governance capacity, environmental degradation, and access to social capital.

Risk assessment has long operated under the paradigm that wealthier people, communities, and countries are less vulnerable to hazards. There is an assumption that they have the resources to counter hazards and losses, while poorer communities are uniquely susceptible to ecological upheavals. This view correctly identifies the disproportionate impacts experienced by poor communities, which often lack the resources to prepare for, respond to, and recover from disasters.

However, the era of complex risk is upending that paradigm. Although poor communities often do bear the brunt of climate and ecological stress, wealthy regions may be vulnerable not in spite of their advanced infrastructure and technology, but because of it. Wealth and technology can lull societies into a false sense of security, reinforcing mental models that assume everything is under control. Perhaps more critically, this overconfidence amplifies vulnerability to the unexpected as novel hazards and unprecedented combinations of familiar threats become increasingly likely.

The February 2021 failure of the Texas power grid is an object lesson. The Texas grid is highly sophisticated and

optimized for typical regional weather, but it is also known to be vulnerable to winter storms. Officials chose to disregard warnings about these vulnerabilities, so when a rare weeklong freeze set in, pipelines and turbines predictably iced over, and power generation plummeted. The rolling blackouts that followed left millions in the dark and hundreds dead.

A secondary effect of the Texas freeze demonstrated how vulnerability can easily skip geographic boundaries. Semiconductor supplies were already depleted by pandemic lockdowns, and the disaster sent four Texas fabrication facilities offline, squeezing global semiconductor supplies further. Today, wealthy countries are likely to access highly interdependent supply chains to mitigate risks. But these same supply chains can also magnify the effects of disruption due to hazards, creating new forms of fragility.

Technological dependencies can translate into vulnerabilities if risks aren't anticipated and if anticipated risks go ignored. For example, Israel relies on desalination to meet half of its water needs, requiring an uninterrupted energy supply and functioning infrastructure. A large-scale power outage or a deliberate attack on key desalination facilities could quickly trigger severe shortages—turning the country's technological strength into a vulnerability.

In sum, the notion that wealth and technology invariably reduce vulnerability is flawed. Wealth and technology can be used to harden societies against risk, but when complex systems break down, the very advantages enabled by wealth and technology can become failure points. A modern framework for risk must account for this broader understanding of what vulnerability means and who may be vulnerable. Future models must take this new paradigm of security and vulnerability into account.

Exposure: the danger of living in the wrong place—or under the wrong system

Exposure is traditionally defined by proximity to risk-prone areas, such as floodplains, seismic faults, and the edges of dry forests. The dense communities of Los Angeles County, such as Malibu, Altadena, and Pacific Palisades, encroach upon wildlands that burn easily. In low-lying countries such as Bangladesh, huge populations are exposed to rising seas that salt their croplands and contaminate freshwater. Coastal megacities from Lagos to Shanghai grapple with the dual threats of land subsidence and intensifying storm surges, placing millions more in harm's way.

But physical proximity to hazards is not the only source of exposure. When people build in coastal floodplains, subsidize risky infrastructure, and rely on fragile supply chains, they create exposure even for those living far from the immediate danger zone.

Consider how the costs of insurance spread local risks across society. When wildfires and other events devastate homes, insurers suffer massive losses. This raises costs for policyholders everywhere while also straining insurers' capacity to provide coverage. Where public insurance is available, as in California, taxpayers pick up the bill for cost overruns.

Similarly, the global nature of supply chains spreads the effects of both disasters and slow-motion ecological degradation to far-flung geographies. These complicated systems are designed for ultra-efficient operation—but only under normal conditions, making them brittle and prone to breaking. Together, globalization and systemic fragility increase the number of people exposed to risk. In 2011, floods in Thailand hit hard-drive manufacturers, disrupting global tech manufacturing and ultimately affecting auto manufacturers in other countries. In another example, global demand for beef depends on supply chains reaching the Brazilian Amazon, where the beef industry drives the clearing of forests to create pastures, altering rainfall patterns, causing erosion, and reducing biodiversity.

Understanding exposure more comprehensively presents both challenges and opportunities for risk managers. The challenge lies in mapping immediate physical proximity in addition to the complex web of economic, social, and ecological connections that transmit risk across space and time. But this also presents an opportunity: By recognizing these extended modes of exposure, managers can identify intervention points where relatively small changes—such as diversifying supply chains, strengthening food systems, or creating redundant infrastructure—can significantly reduce cascading impacts. Risk assessments must move beyond static maps to dynamic models that capture how exposure evolves through interconnections.

Response: why nothing changes after disaster strikes

Response reflects the agency people have in shaping their own risk—their capacity to anticipate, absorb, and adapt to hazards rather than simply endure them. This encompasses immediate emergency actions, recovery efforts, and long-term strategies aimed at reducing future vulnerability and exposure to hazards. However, response can also heighten risk, such as through inaction, denial, or counterproductive measures. Examples include ignoring evacuation warnings, rebuilding in high-risk locations after disasters, failing to heed scientific warnings about emerging threats, or implementing well-intentioned policies that inadvertently encourage risky behavior.

The effectiveness of response to complex risk is increasingly undermined by two critical factors. First, misinformation—amplified by algorithm-driven media and emotion-laden content—erodes trust in emergency warnings, scientific expertise, and disaster management, making it difficult for people to know what actions to take. Misinformation increasingly functions as a cognitive hazard in its own right, undermining our ability to process information and update our mental models. The aftermath of Hurricane Helene illustrates this problem: False allegations about politically motivated aid

distribution poisoned public trust, resulting in threats against aid workers. Victims were forced to turn to local organizations that, while responsive, lacked the resources and coordination capacity needed for large-scale disaster recovery.

Second, reactive governance prioritizes immediate recovery over strategic adaptation. Under the isolated-incident model, federal, state, and local governments prioritize immediate recovery funding and restoration of the status quo. New infrastructure merely replicates what it replaces, rather than improving on the resilience of old systems. Proactive prevention, adaptation, and strategic relocation receive little support because public policy does not encourage them. The result is that recovery processes fail to incorporate evolving knowledge about complex risks.

These are not new problems, but their effects are magnified in an era of complex risk, when deeply interconnected systems ensure that failures spill across domains. Prevention and adaptation have never been politically easy, thanks in part to cognitive biases, but in today's politicized environment, meaningful change is increasingly possible only at the local level.

A partial path forward: local resilience

As federal agencies dismantle key environmental and health data systems, responsibility for risk awareness and disaster response is being forced onto individuals, local communities, and nongovernmental organizations. Effective response must now percolate at the local level as states, counties, and towns have little choice but to rely on independent risk assessments and develop their own proactive planning to prevent cascading failures. This federal retreat will almost certainly weaken hazard response in the United States; however, there are models of more responsive and adaptive management systems from other countries that suggest what coordinated action could achieve.

Japan, for instance, has developed one of the most advanced disaster management systems in the world, moving beyond single-event planning toward integrated approaches that account for cascading crises. The system emphasizes early warning, layered contingency planning, and community engagement, with citizens trained in firefighting, search and rescue, and first aid. Authorities continuously upgrade building codes and design infrastructure to operate under stress from overlapping disruptions. The 2011 Tohoku earthquake and tsunami response demonstrated this approach: Despite the unprecedented scale of the disaster, a combination of accessible supplies, practiced evacuations, and community-level response teams saved thousands of lives.

The Netherlands offers another example. Dutch cities are working to shift from static defenses against flooding, like dikes, toward the concept of "making space for water," such as in Nijmegen's Room for the River program. Instead of building higher barriers, Rotterdam created green roofs and water plazas that serve as parks during dry periods and provide floodwater retention during storms. These programs, part of a nationally supported strategy, embed resilience into local decisionmaking while managing immediate flood risk as well as broader impacts on housing, transport, and public health.

We harbor no illusions about the challenge that lies ahead. If state and local governments are to take pivotal measures—erecting flood barriers, facilitating emergency power supplies, building urban green spaces that soak up floodwaters—then communities will have to learn to come together to advocate for change. This is a massive project. However, there is some hope that pragmatism could prevail at smaller scales of government, where trust is higher and the effects of policy are more easily observed.

Research shows that neighborhoods with stronger social ties and more opportunities for connection—what some scholars call social infrastructure—have better disaster outcomes. Even if citizens distrust distant politicians, communities can still cooperate internally to strengthen risk education, create warning systems, maintain emergency stockpiles, and pursue avenues to limit vulnerability.

Yet we must be clear-eyed about the limits of local resilience. Communities can and must organize to protect themselves, but the cascading, planetary-scale risks at hand fundamentally exceed local capacity. No amount of neighborhood preparedness can address failing insurance markets, collapsing supply chains, or altered atmospheric physics. Local resilience is a necessary triage—not a substitute for the work of coordinated, well-funded, and scientifically informed institutions that are desperately needed at the state, federal, and international levels.

A grasp of the true nature of complex risk—its basis in hazard, vulnerability, exposure, and response—could provide a foundation for local cohesion around shared responsibility. This social infrastructure that helps communities survive disasters must ultimately become the foundation for political pressure demanding governance scaled to match society's predicament. Local successes can establish the trust necessary for larger-scale cooperation and evidence-based programs that can be scaled up to regional and national levels. In this moment of federal abandonment, local action is where we must focus—but it cannot be where we end if we hope to successfully navigate what's coming.

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